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B3W 22 46A 51 67 70C 7B4C 7BY 8B4C 8BY

(56) Documents cited
GB A 2068493

(58) Field of search
B3H B3U

(54) Installing a self-attaching fastener in a panel

(57) A self-piercing fastener (150) such as a stud, bolt or nut, has a body portion (152, 154) and a self-piercing and riveting annular wall portion (156) having an open free end defining an angled piercing surface (166) which slopes outwardly from the inner surface (164) of the wall (156) and a curved surface (160) adjacent the outer surface (158) of the wall (156). The fastener is secured to a panel (206) by driving the fastener into the panel supported on a die member (180) having an annular concave die cavity (202) surrounding a central projecting die portion (184) having a peripheral piercing edge (196) which co-operates with the piercing surface (166) so that a slug (216) is pierced from the panel. The slug (216) is forced into the wall as the free end of the wall (156) is simultaneously deformed radially outwardly by the die cavity (202) to form a U-shaped annular channel (156*c*) and the portion of the panel (218) adjacent the pierced edge is drawn and subsequently driven by the body portion (152) into the channel (156*c*).

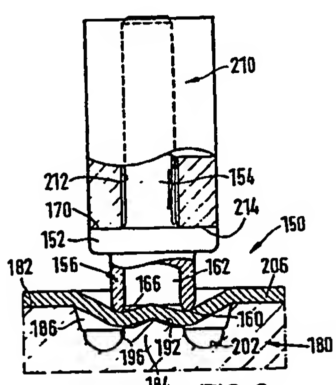

FIG. 8

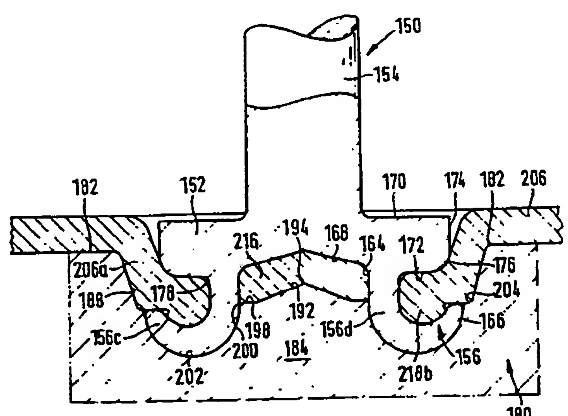

FIG. 14

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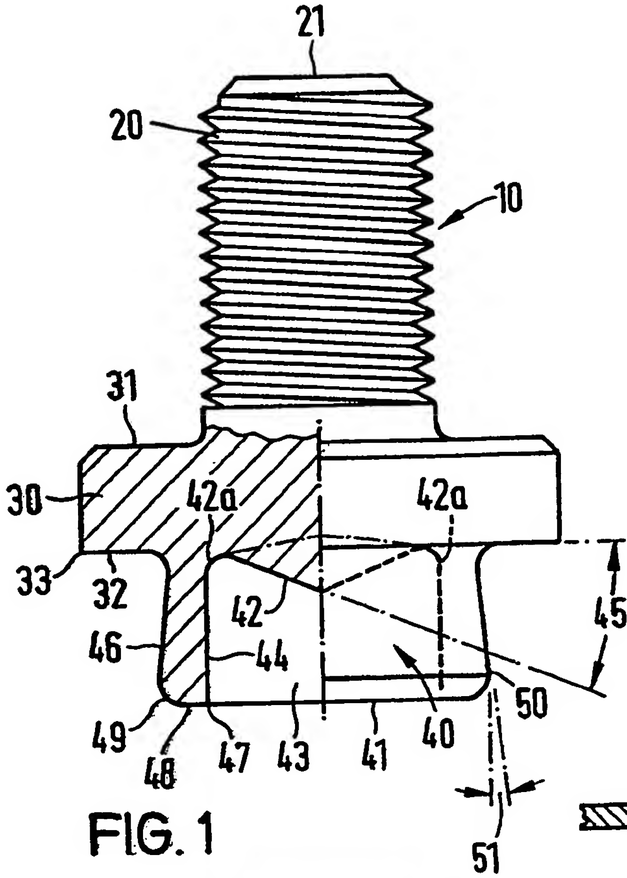
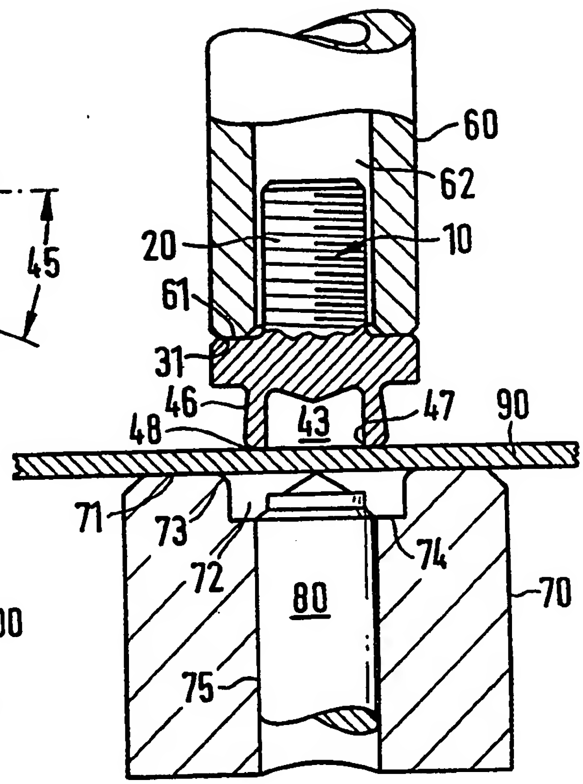


FIG. 1



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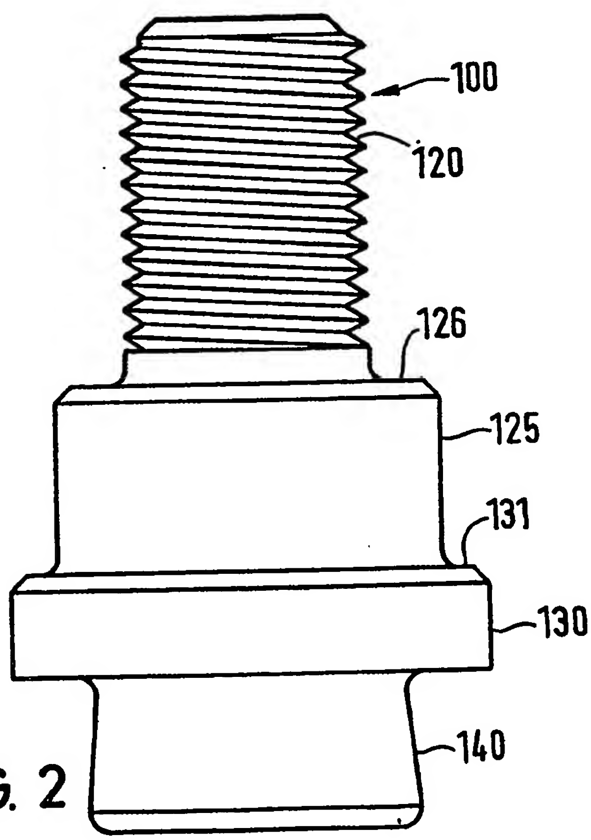

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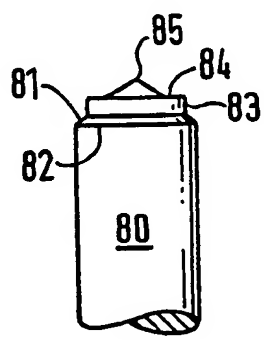

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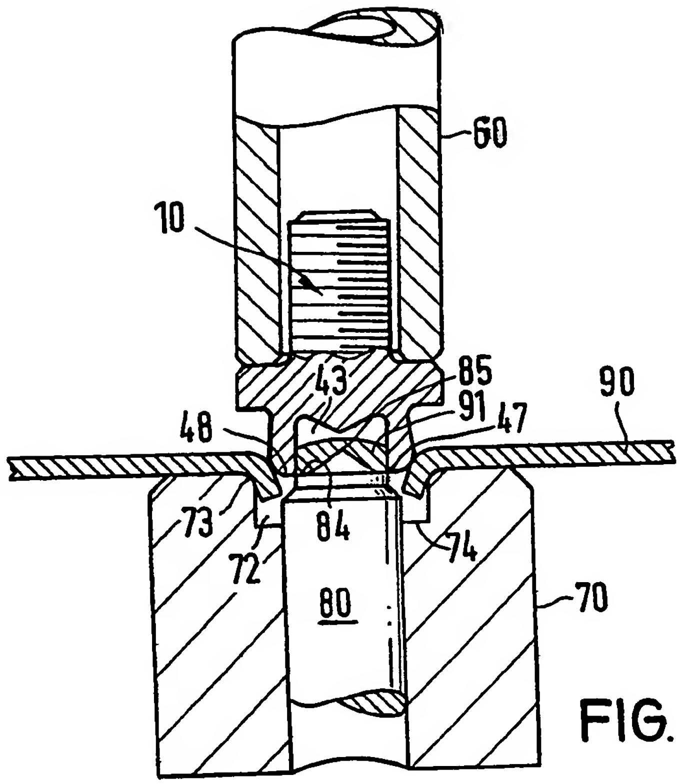
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FIG. 5

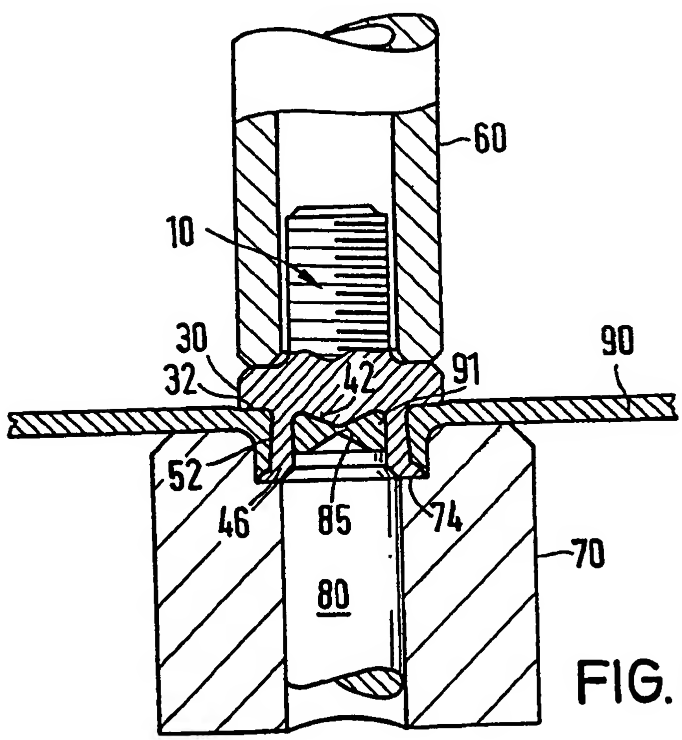
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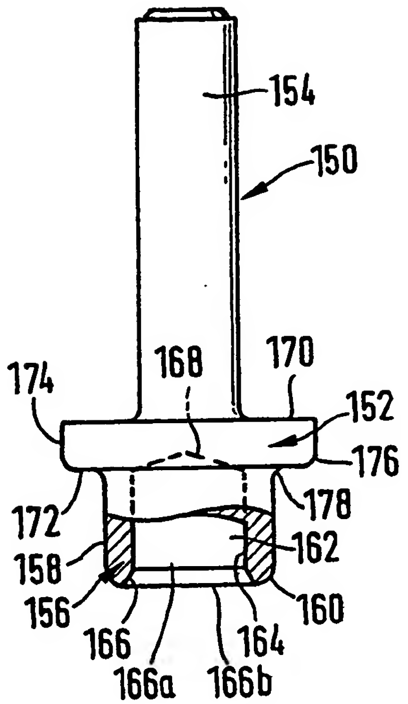
FIG. 6



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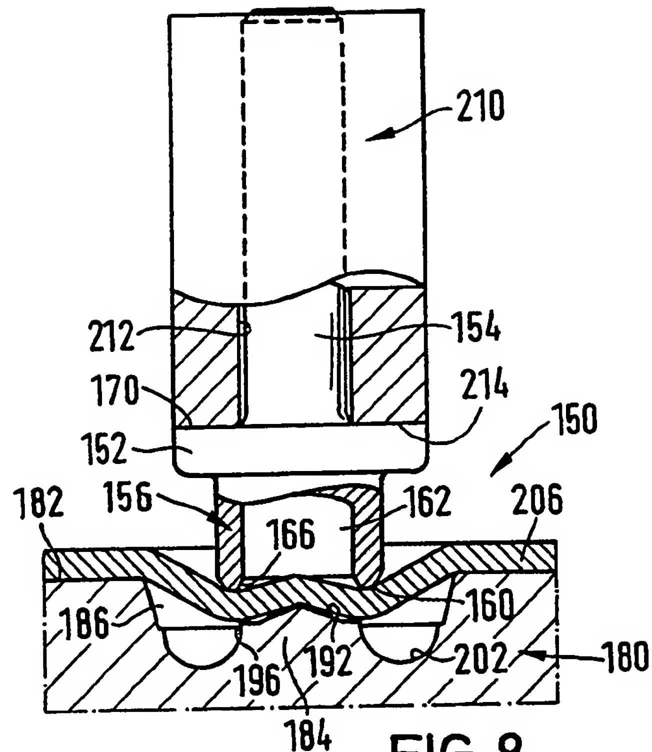

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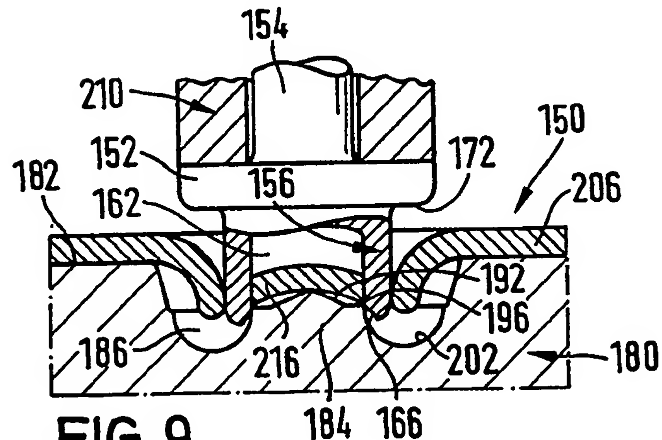

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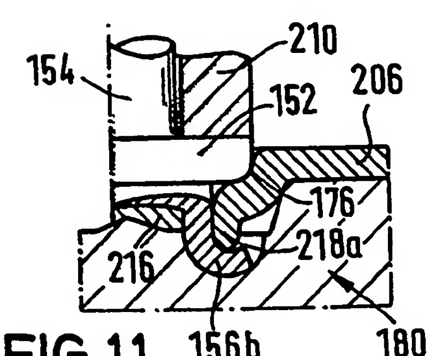

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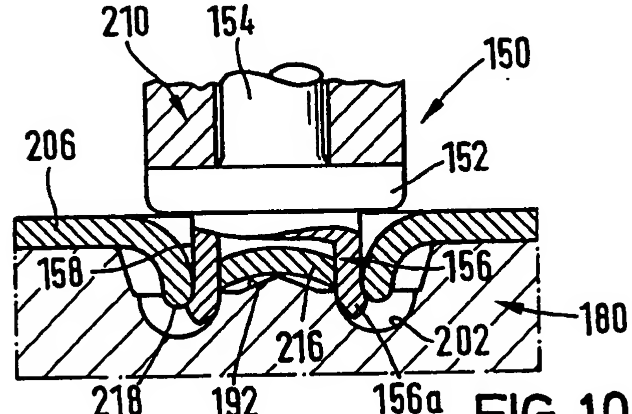


FIG.10

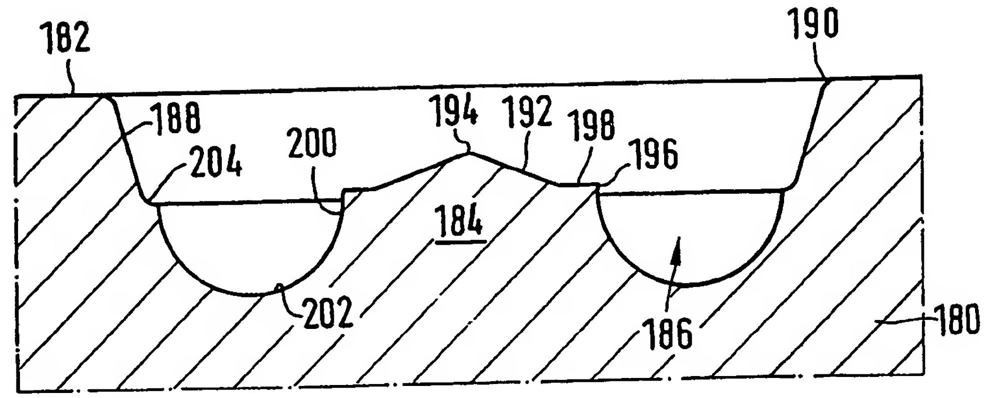
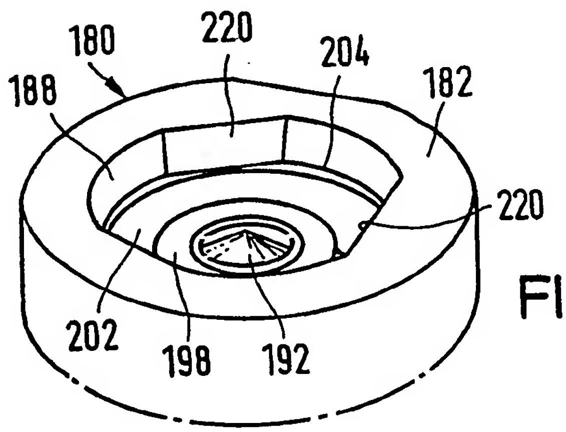


FIG. 12



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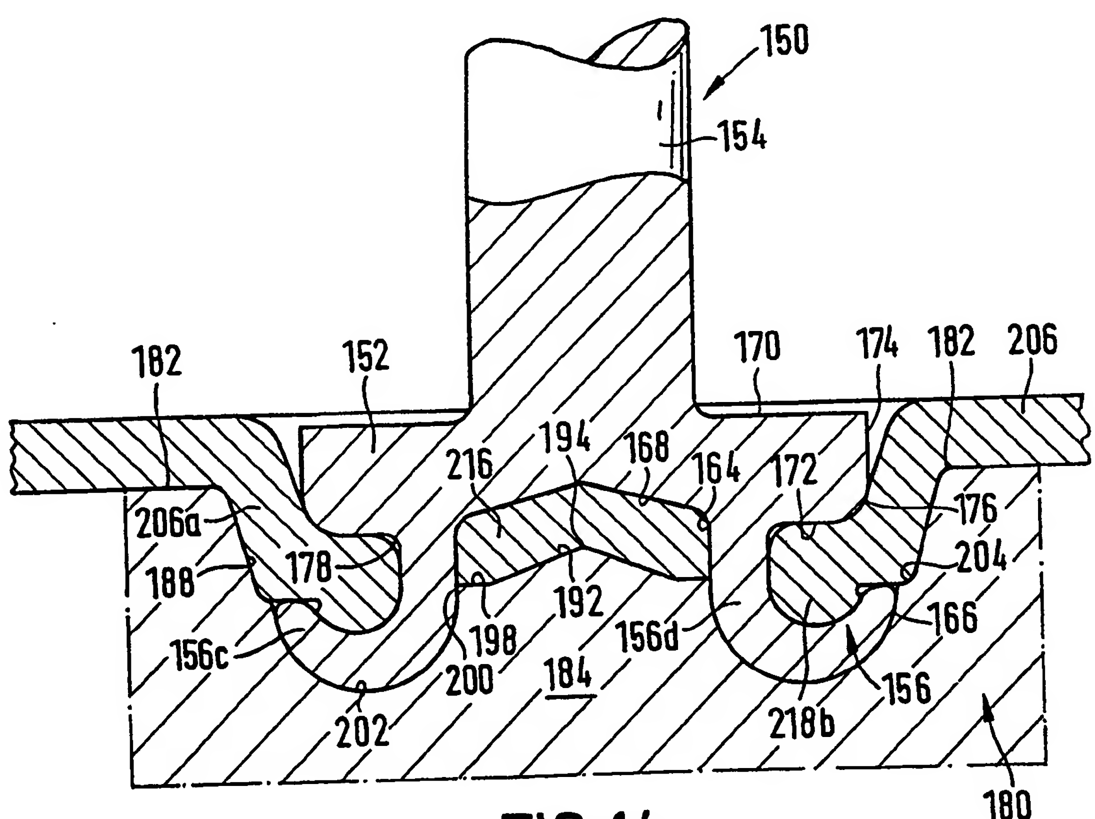

FIG. 14

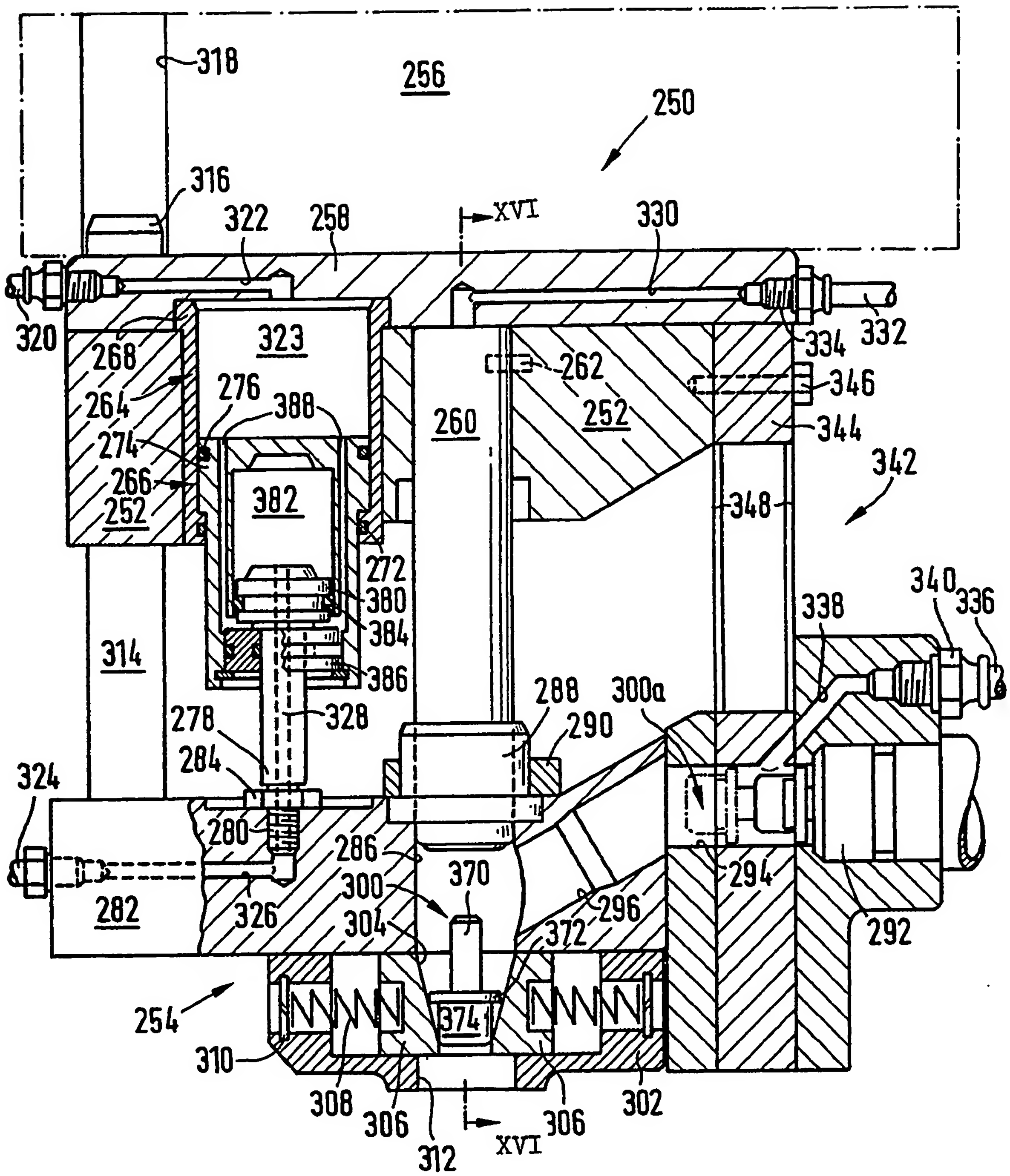

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FIG. 15

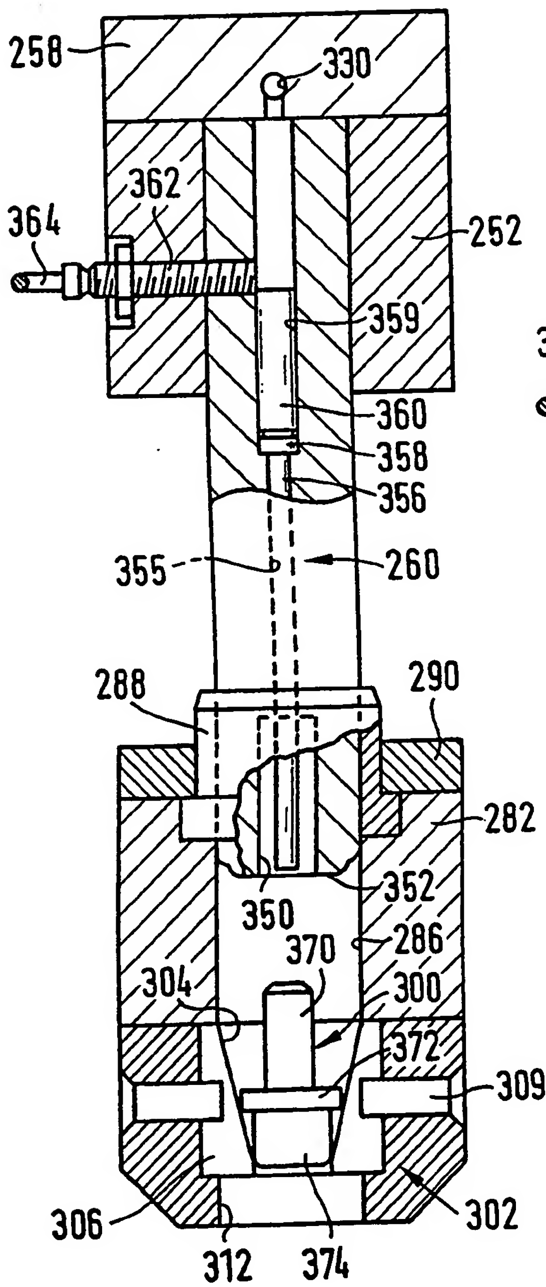
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FIG. 16

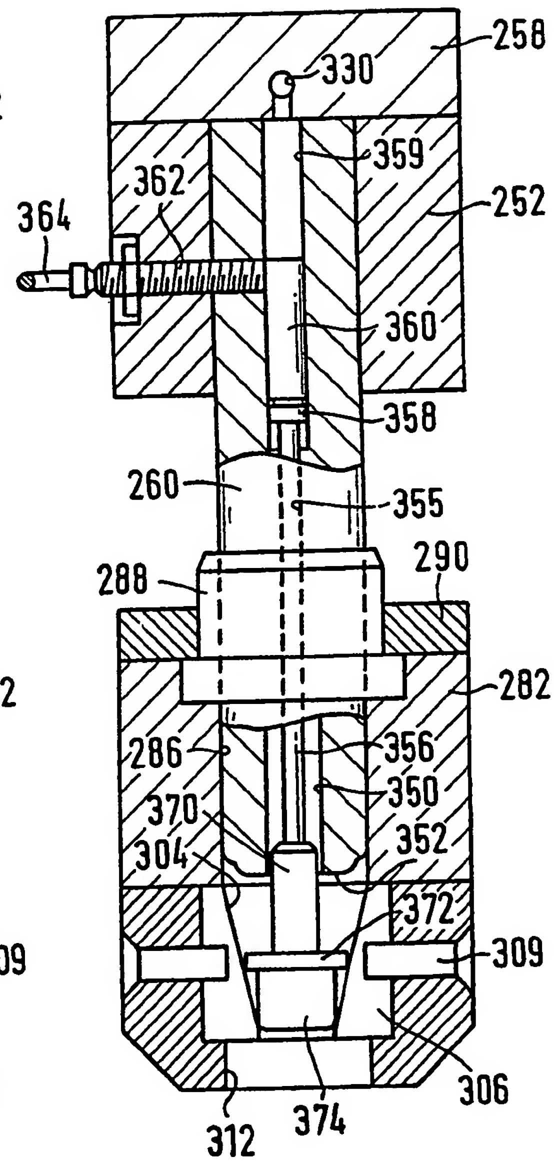
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FIG. 19

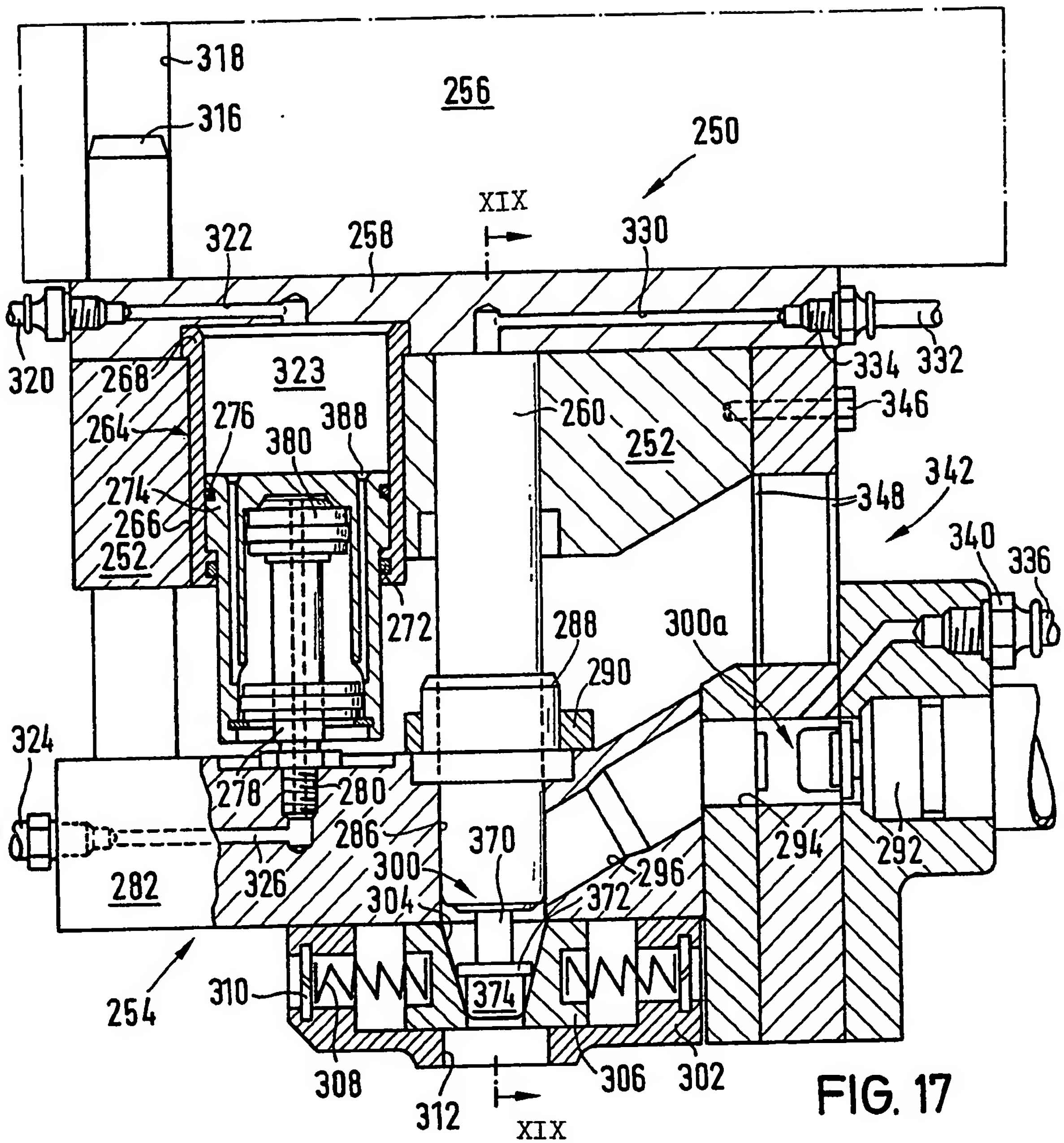
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FIG. 17

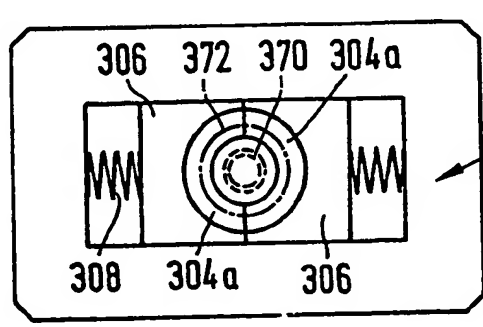
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FIG. 18

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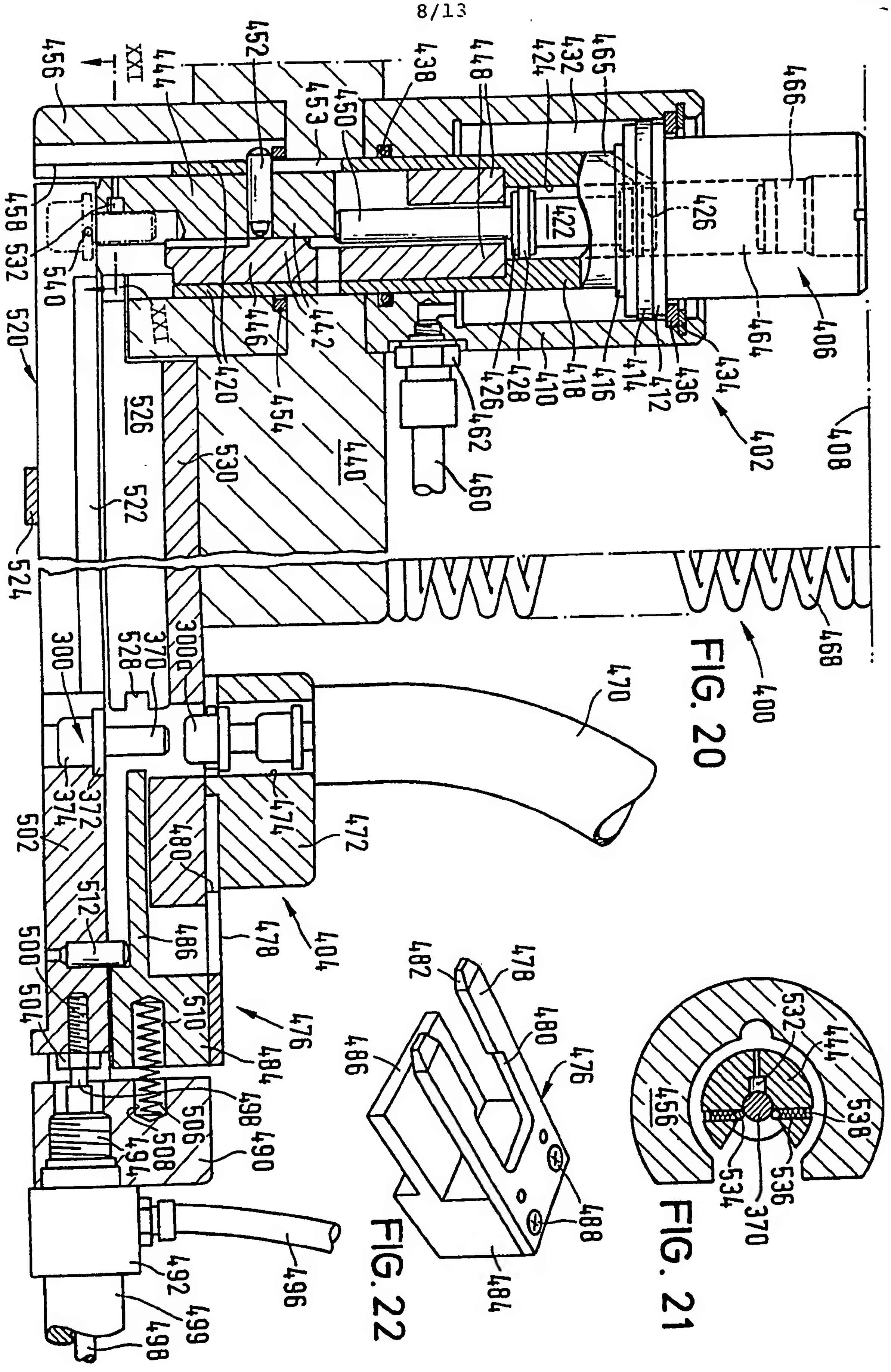

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FIG. 22

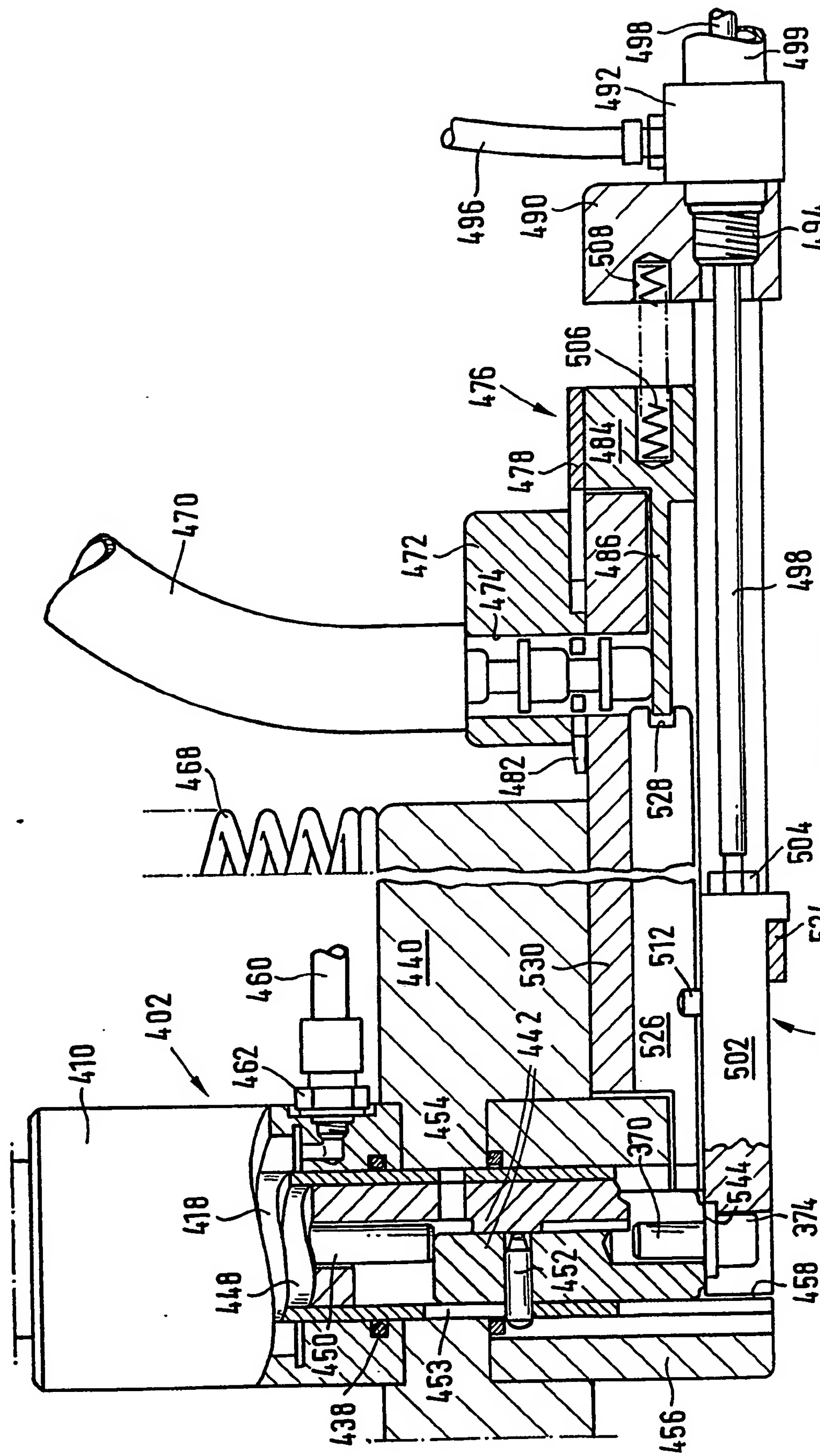

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FIG. 23

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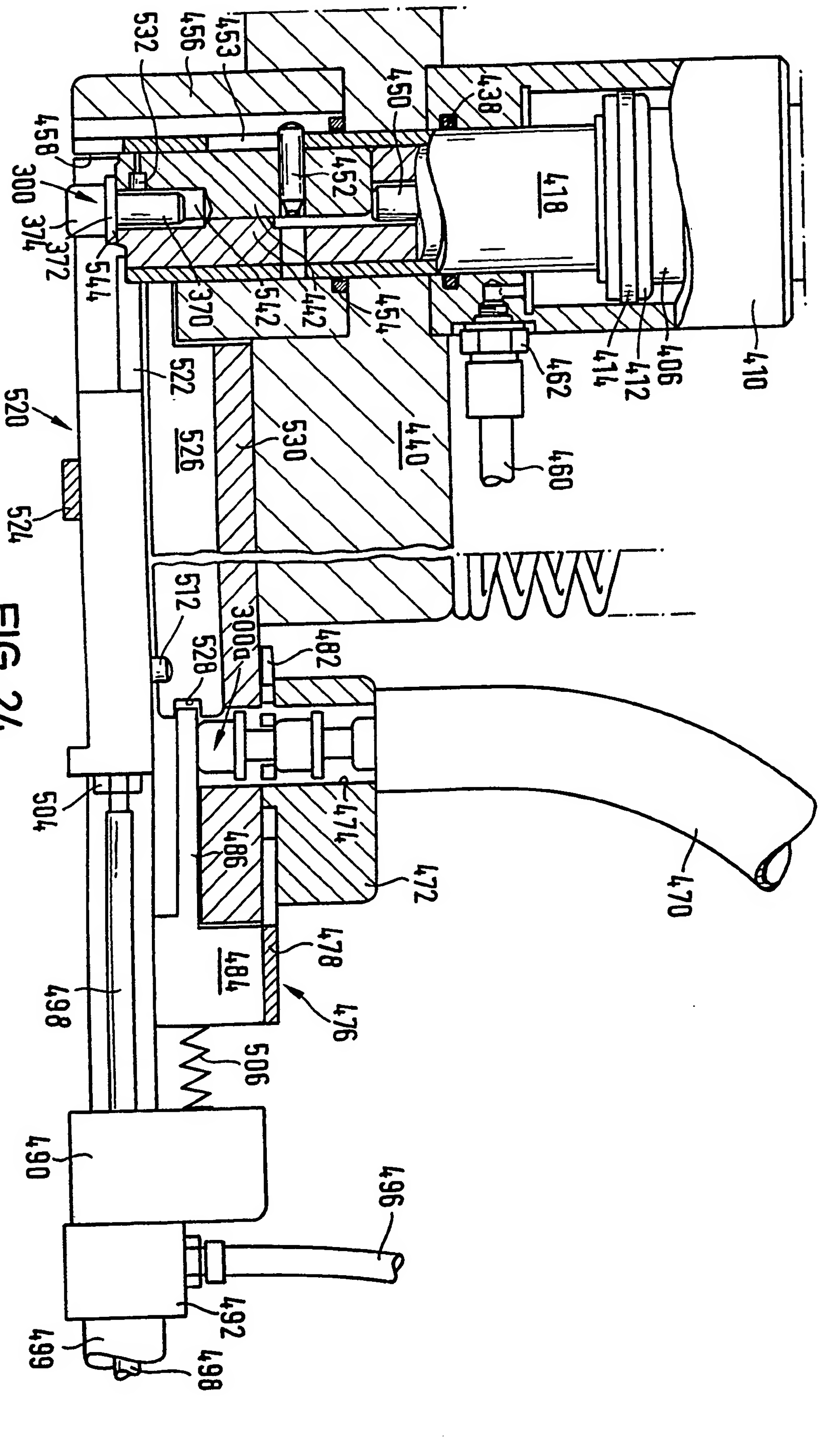

FIG. 24

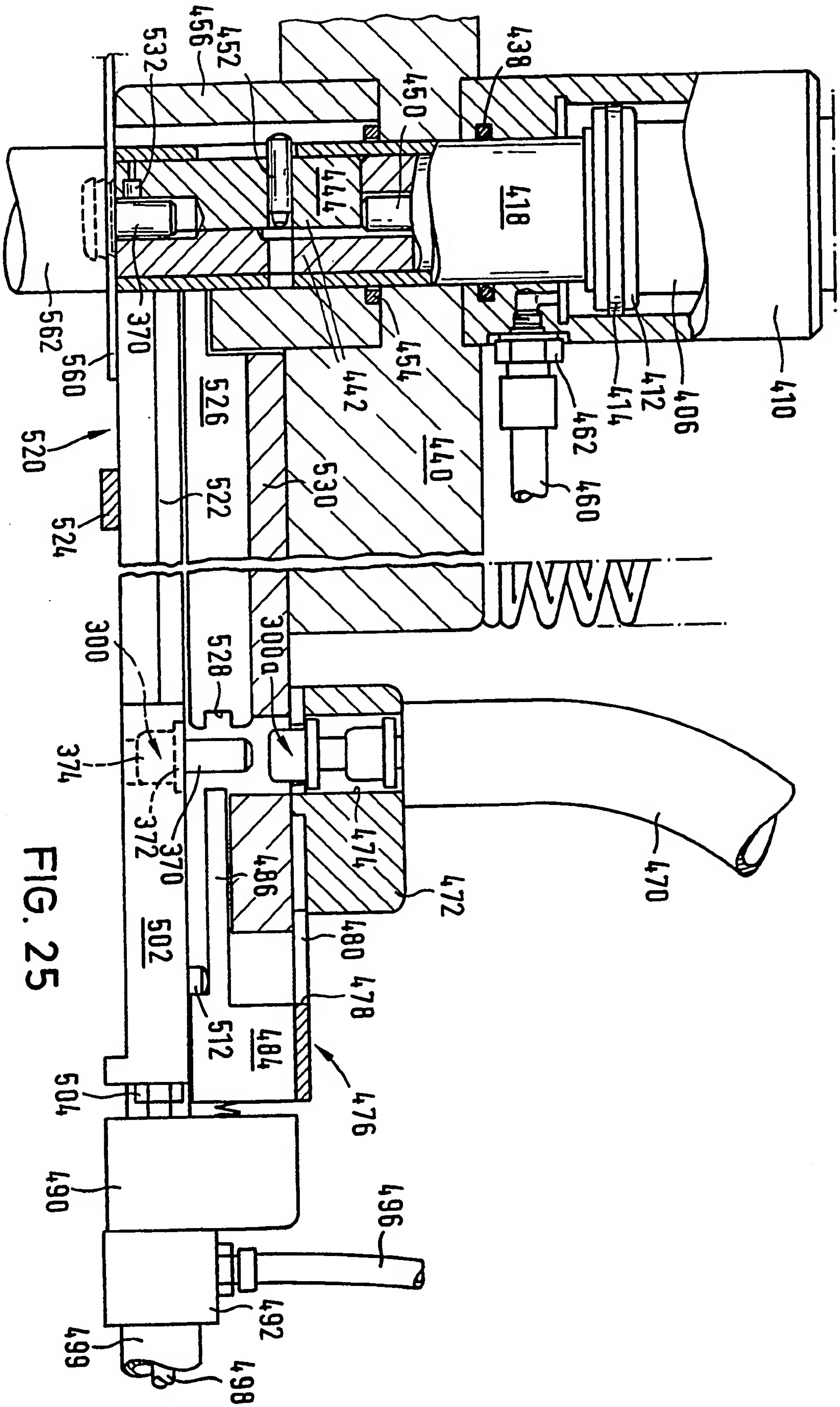
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FIG. 25

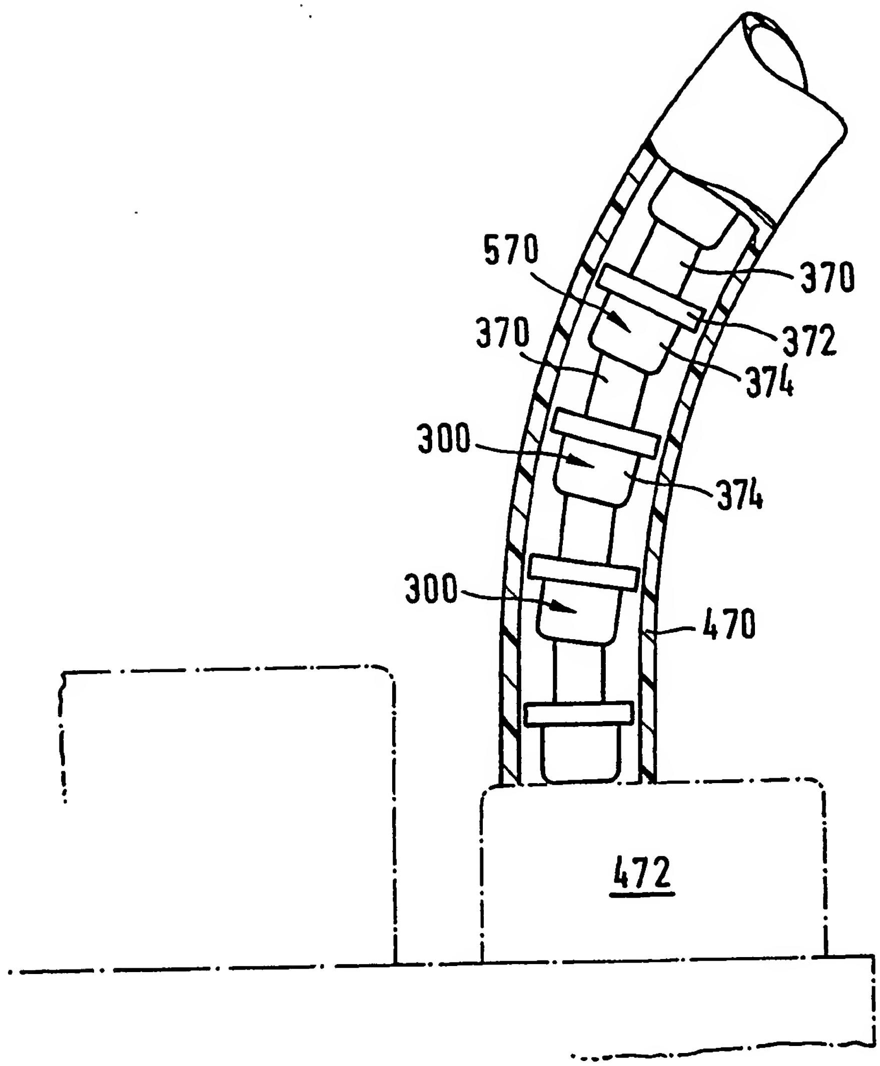

FIG. 26

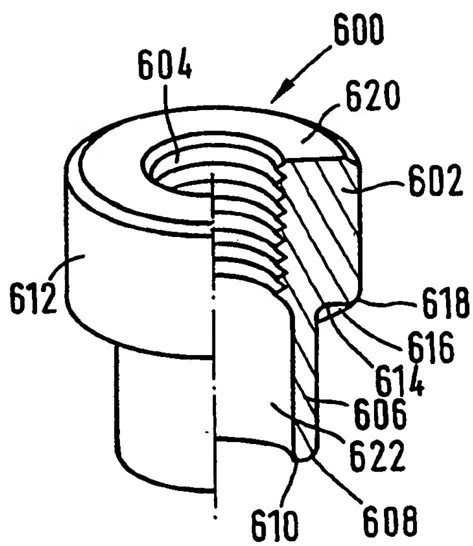

FIG. 27

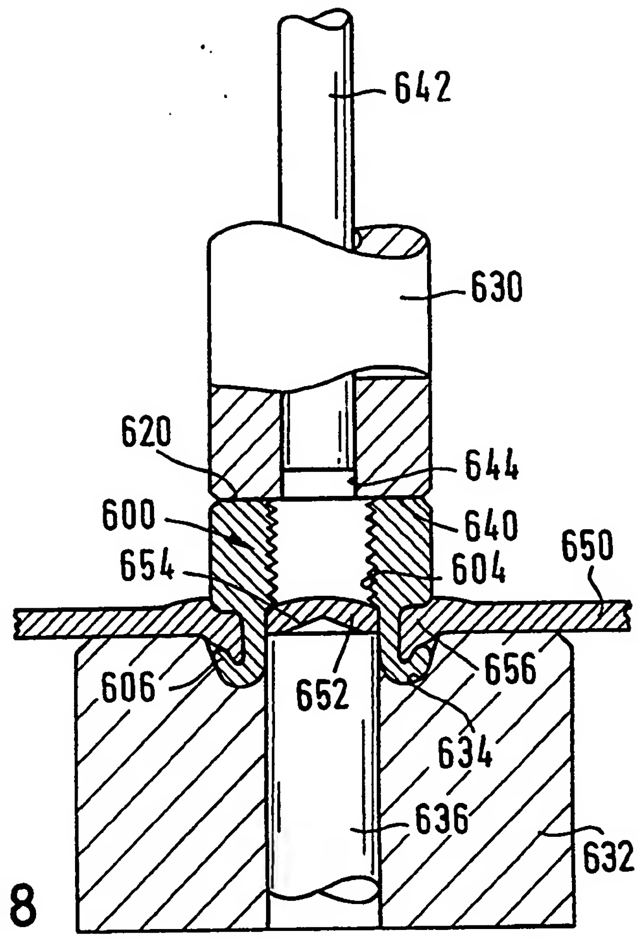

FIG. 28

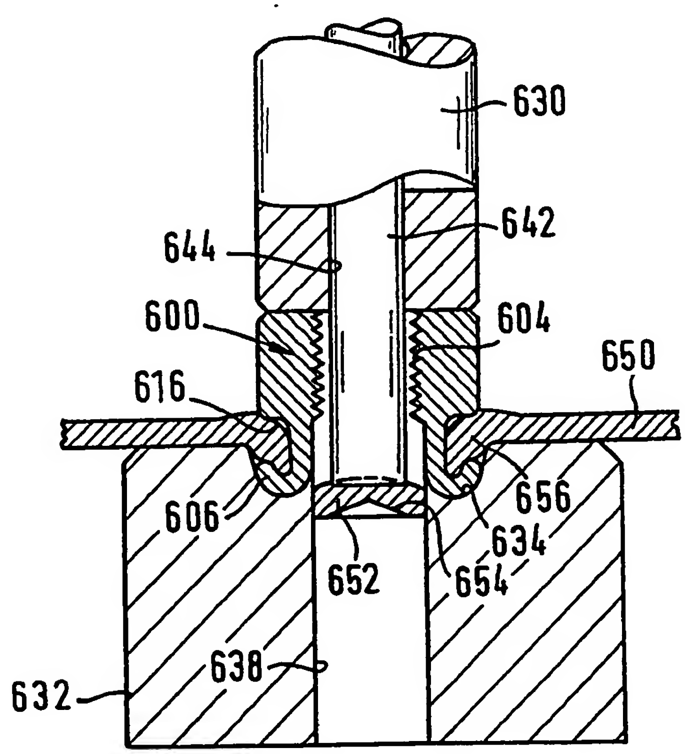

FIG. 29

SPECIFICATION

Self-attaching fastener, and methods and apparatus for installing the fastener in a panel

The present invention relates to self-attaching fasteners, including studs, bolts, nuts and the like, and is particularly concerned with such fasteners of the self-piercing and riveting type. The invention also relates to methods of fixing such fasteners to a panel, and to installation apparatus for use in carrying out the methods, including an installation head which feeds, orients and drives the fastener into the panel, and a die member which deforms the fastener and panel during installation of the fastener.

Self-piercing nuts which may be simultaneously clinched to secure the nut in the pierced panel opening are known, for example from our United States Patents Nos. 3 299 500 and 3 314 138. Also known are a number of self-riveting nuts, including nuts having an annular skirt portion which is deformed radially outwardly in a die member to form a mechanical interlock with the panel when fixing the nuts, examples being shown in United States Patents Nos. 3 938 239 and 4 108 257. The self-riveting nuts disclosed in these patents are, however, secured to a panel having a prepierced panel opening, thus requiring at least two separate operations. Furthermore, the riveted nut is not suitable or sufficiently rigid to secure a stud, bolt or other similar member having a projecting portion extending from the plane of the panel.

A method and apparatus for attaching a stud-like fastener to a plate or structural steel member, in which the stud includes an annular end portion which penetrates the plate and which is deformed radially inwardly around a plug formed in the plate is disclosed in United States Patents Nos. 4 193 333 and 3 871 264. However, the technique disclosed in these Patents is not suitable for many applications, and particularly not for automotive applications requiring a rigid connection between a stud fastener and a relatively thin panel.

United States Patents Nos. 1 976 019; 2 456 118; 2 521 505; 3 436 803; 3 754 731; 4 039 099 and 4 092 773 disclose various fastener riveting techniques in which the fastener includes an annular end portion which is press-fitted through an opening in a panel, and which is then riveted or radially outwardly deformed by a die member having an annular semi-toroidal die cavity which may include a projecting central die portion which is received in the annular riveting end of the fastener. The prior art does, of course, disclose automatic riveting apparatus and driving tools, but these are not suitable for installing the stud-like fasteners described herein, nor for feeding, orienting and driving self-piercing and riveting fasteners of the type described in mass production situations, in which the annular self-piercing and riveting wall of each fastener must be accurately aligned and oriented with a die member prior to its installation.

In our UK Patent No. 2 068 493 we describe a stud bolt having an annular piercing and riveting portion at one end, and a method and apparatus for fixing the bolt in a panel in which the slug which is pierced from the panel when the bolt is punched through it is jammed within the annular portion to enhance the anchorage of the bolt in the panel formed by deforming the free end of the annular portion and the panel surrounding the pierced opening in engagement with each other. The aim of the present invention is to improve stud and other fasteners of this type, and to provide an improved method and apparatus for installing the fasteners in a panel, preferably in a single continuous operation, which will provide a rigid attachment in relatively thin panels, even in the case of stud-like fasteners having a projecting shank portion, and which is suitable for use in mass production industries, particularly the automotive industry, using automatic presses.

According to one aspect of the present invention, a self-piercing and riveting member for attachment to a panel comprises a body portion, and a self-piercing and riveting annular wall which extends from the body portion and which has an outer surface, a generally smooth inner surface, and an open free end having an annular piercing face angled outwardly from the inner surface for piercing a slug from the panel having a diameter greater than the diameter of the inner surface, and a curved junction with the outer surface, the annular wall defining a socket for receiving the panel slug and having a bottom wall at the opposite end of the inner surface from the piercing face.

With this construction the slug which is pierced from the panel by the chamfer-like piercing face becomes a tight force fit within the socket defined by the annular wall to support the wall against collapse as the free end of the annular wall is deformed radially outwardly to form a mechanical interlock with the panel. The panel slug is deformed against the bottom wall of the socket, securely retaining the slug in the socket, and the slug becomes an integral part of the assembly. The construction is particularly suitable for stud fasteners and the like, but not for nut fasteners requiring a through passage. In this case the bottom wall must be omitted and the slug removed after attachment of the fastener to the panel, and preferably the free end of the annular wall has a relatively sharp piercing edge adjacent the inner surface of the wall instead of the outwardly angled piercing face.

According to a second aspect of the invention a method of attaching a fastener to a panel, the fastener comprising a body portion and a self-piercing and riveting annular wall which extends from the body portion and which was inner and outer surfaces and an open free end portion having a piercing surface adjacent the inner surface, comprises

a) locating the fastener opposite the panel with the free end of the annular wall facing the panel and a die member located on the opposite side of the panel;

b) piercing a slug from the panel with the piercing surface of the annular wall;

c) carrying the pierced panel slug into the space bounded by the annular wall on the die member;

d) deforming the free end portion of the annular wall radially outwardly to form a generally U-shaped channel opening towards the body portion of the fastener and the pierced edge of the panel; and,

e) deforming the pierced edge of the panel against the outer surface of the annular wall into the generally U-shaped channel, forming a mechanical interlock

between the panel and the self-piercing and riveting annular wall of the fastener.

In the case of a fastener, such as that in accordance with the invention, having a piercing surface in the form of an annular chamfer face angled to the inner surface of the annular wall so that the slug pierced from the panel has a diameter greater than the internal diameter of the annular wall, the slug is forced by the die member into the spaced bounded by the annular wall and supported therein in binding engagement with its inner surface, preferably at the position of greatest internal stress resulting from the radially outward deformation of the annular wall and thus preventing inward collapse of the wall.

Preferably, the panel portion adjacent the pierced edge is driven into the annular U-shaped channel, deforming the pierced edge in the U-shaped channel and forming a reinforcing enlarged annular bead enclosed within and contacting the inner surface of the U-shaped channel. For this purpose the body portion of the fastener preferably includes a base portion having a side surface and a bottom surface which are joined by an arcuate surface, the annular wall being integrally joined to the bottom surface of the base portion inwardly from the side surface, and the base portion of the fastener is driven into the panel following the piercing of the slug from the panel, simultaneously deforming the free end of the wall radially outwardly to form the generally U-shaped channel and deforming the panel adjacent the pierced edge by counter rotating the edge portion within the channel. The base portion thus becomes recessed in the panel, preferably forming a relatively flush mounting of the base portion in the panel so that when the fastener is a stud-like fastener, the shank portion of the stud extends from the plane of the panel.

Preferably the die member comprises an annular concave die cavity surrounding a projecting central die portion which is coaxially aligned with and receivable within the inner surface of the annular wall and which has its free end including a central conical surface having a relatively sharp apex, so that the panel is deformed and domed on the central conical surface at the free end of the central die portion before the panel is pierced.

Preferably the die member includes a panel supporting shoulder located on at least two sides of the die cavity, and the free end of the central die portion has a relatively sharp piercing edge at its outer edge and surrounding the conical surface, the piercing edge being adapted to generally co-operate with the piercing surface of the fastener to pierce a slug from a panel supported on the die shoulder, and the shoulder blending into an inclined surface of the die cavity for receiving the panel as the panel is deformed into the die cavity during installation of the fastener.

The central die portion may be a fixed integral part of the die member, preferably with its conical surface spaced below the panel supporting shoulder so that a panel will be first deformed from the plane of the shoulder into engagement with the conical die surface and thereby domed prior to having a slug pierced from it.

Preferably the annular concave die cavity comprises a smooth concave arcuate annular surface extending from adjacent the piercing edge of the central die portion through the bottom of the die cavity to an annular lip generally parallel to the shoulder and spaced above the bottom of the cavity, and the outer inclined surface of the die cavity extends between the shoulder and the lip, smoothly merging with the shoulder and lip through arcuate surfaces. The annular lip supports the panel portion adjacent the pierced panel edge as the pierced edge is deformed into the hook or U-shaped channel formed by the deformed free end of the annular wall of the fastener.

The construction of the die member constitutes another aspect of the present invention, and the combination of the fastener and the die member with a second die member for moving the fastener relative to the first member constitutes a further aspect in the form of a die set assembly for attaching the fastener to a panel in one continuous operation, wherein the panel is supported on the shoulder of the first die member and is first deformed into the die cavity by the second die member, the panel is then pierced between the co-operating piercing surfaces of the fastener and the central projecting die portion, and finally, the annular wall of the fastener is deformed radially outwardly against the surface of the die cavity, and the pierced panel edge is deformed into the hook or U-shaped channel formed by the free end of the annular wall so that a relatively rigid mechanical interlock is formed between the self-piercing and riveting annular wall of the fastener and the panel adjacent the pierced panel edge.

According to a further aspect of the invention, the product comprises a fastener secured rigidly to a panel, the fastener having a body portion and an annular wall portion which extends from the body portion and which comprises a first tubular portion adjacent the body portion and having generally parallel walls and a second radially outwardly hook-shaped end portion, and the panel having a slug pierced from it by the annular wall and disposed in the first tubular portion of the wall in engagement with its interal surface and a portion adjacent the pierced edge of the panel which is displaced from the plane of the main portion of the panel so that it engages the exterior surface of the first tubular portion of the annular wall and is deformed in the second hook-shaped portion, forming a mechanical interlock between the panel and the annular wall portion of the fastener.

According to yet another aspect of the invention, apparatus for installing self-attaching fasteners of the kind described in a panel comprises the die member and an installation head for receiving the self-attachinng fastener, orienting the fastener for installation, and driving the fastener against the panel and into the die member to secure the fastener to the panel. In a typical application, the die member is located on the bottom shoe of a mechanical, hydraulic, or pneumatic press, such as is used in the automotive industry to form panels, brackets and the like. The installation head is attached to the upper reciprocating die shoe, such that a fastener is attached to the panel with each stroke of the press. It will be understood, however, that the die press may include several installation assemblies, whereby several

fasteners are installed with each stroke of the press. Furthermore, the arrangement may be reversed, so that the die member is located on the movable die shoe and the installation head is secured to the fixed die shoe.

The installation head of apparatus in accordance with this invention is particularly, although not exclusively, designed for installation of stud-like fasteners having a projecting portion, such as a shank, extending from the body or head portion of the fastener. This type of fastener presents unique installation problems in mass production processes because the elongated fastener must be accurately oriented in the head and aligned with the die member to prevent damage to the installation apparatus.

In one embodiment of the apparatus the installation head comprises a base member, a plunger which is movable with the base member, a nose member which is spaced from and movable relative to the base member and which has a plunger passage through which the plunger is slidable and a fastener feed passage communicating with the plunger passage, the plunger passage having a generally conical recess which receives and supports the self-piercing and riveting wall of a fastener fed into the plunger passage from the feed passage, thereby centering the fastener in the plunger passage ready for installation in a panel by the plunger, and the plunger having a bore in its leading end arranged to receive the free end of the fastener body portion upon movement of the nose member relative to the plunger following receipt of a fastener in the conical recess of the plunger passage to assure orientation of the fastener ready for installation, and actuating means for causing the apparatus to relatively move the plunger through the plunger passage to drive the oriented fastener out of the plunger passage and into a panel located opposite the passage.

In this embodiment of the installation head, the conical recess is preferably defined by at least two spring biased members which are cammed apart by the fastener to allow the fastener out of the plunger passage when it is driven by the plunger against the conical surface defined by the spring biased members. Also, preferably the base member is attached to the movable platen of a press, and the base and nose members are operably interconnected by a fluid pressure operated mechanism adapted to move the nose member relative to the base member to move the body portion of the fastener into the plunger bore, the actuating means operating the press to close the space between the members and drive the plunger through the plunger passage to install the fastener in the panel.

In a second embodiment of the apparatus designed specifically for fasteners having an elongated body portion, the installation head comprises a housing having an elongated plunger reciprocable in a plunger passage, and transfer means for feeding the fastener along a path transverse to and intersecting the plunger passage, the plunger having a longitudinally extending bore for receiving the elongated body portion of the fastener and an end portion arranged to bear against the annular wall portion, and the plunger being formed by at least two longitudinally extending parts which intersect the bore and of which a first part has a concave portion of the bore facing the transfer means feed path and a second part is movable relative to the first part and is adapted to close the bore and block the feed path, the apparatus also comprising actuation means for longitudinally moving the second plunger part relative to the first plunger part to open the concave bore portion of the first part and allow the transfer means to feed a fastener along the path into the plunger passage so that the body portion of the fastener is received in the bore portion of the first plunger part, thereby locating the fastener oriented for installation, and then closing the second plunger part around the body portion of the fastener before actuating means for driving the plunger through the plunger passage to install the oriented fastener in a panel located opposite the plunger passage.

The self-attaching stud fasteners in accordance with the present invention are particularly adapted for transfer from a hopper or other source of fasteners to the installation head through a flexible tube. As described, the stud fasteners include an elongated shank portion and a tubular riveting wall portion generally coaxially aligned with the shank portion, and preferably this tubular wall portion has an internal diameter greater than the external diameter of the shank portion. The fasteners may then travel in the flexible tube as a stack of fasteners in which the elongated shank portion of each fastener is received in the tubular wall portion of the following fastener, the stack being sufficiently flexible for transfer through the tube.

It should be understood that the self-attaching fastener in accordance with the present invention may be of almost any type. For example, the fastener may be a stud, bolt, nut, or ball joint wherein the end of a shank portion of the fastener includes a ball member or other fastening means. As used herein, "fastener" refers not only to the function of the fastener to attach another structural member to the panel, but also the means of attaching the fastener to the panel. It should also be understood that the self-attaching fastener, the method of installing the fastener in a panel, and the installation apparatus constitutes a complete system, the apparatus being specifically adapted to install the self-attachinng fastener by the method, preferably in a continuous operation. The resulting secured fastener and panel is also unique in that the mechanical interlock between the panel and the self-piercing and riveting wall of the fastener is extremely rigid, and stronger than the panel itself.

Examples of the fastener in accordance with the invention and of the method and apparatus for installing the fastener in a panel will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a part sectioned side view of one form of a self-attaching stud bolt which is disclosed in our UK Patent No. 2 068 493;

Figure 2 is a side view of a second form of self-attaching stud bolt disclosed in Patent No. 2 068 493;

Figure 3 is a part sectioned side view of the stud bolt shown in Figure 1 together with apparatus ready for installing the bolt in a panel;

Figure 4 is a side view of part of the apparatus shown in Figure 3;

Figures 5 and 6 are views similar to Figure 3 illustrating different stages in the method of installing the bolt in the panel using the apparatus;

Figure 7 is a part sectioned side elevation of an example of a self-attaching stud fastener in accordance with the present invention;

Figures 8 to 11 are part sectioned side views of the stud shown in Figure 7 at different stages in the process of installing the stud in a panel using an example of apparatus in accordance with the invention;

Figure 12 is a sectional view of the die member which forms part of the apparatus shown in Figures 8 to 11;

Figure 13 is a perspective view of the die member shown in Figure 12;

Figure 14 is a view similar to those of Figures 8 to 11 showing the stud attached to the panel at the end of the installation sequence;

Figure 15 is a part sectioned side view of one example of installation head apparatus in accordance with the invention, showing a self-attaching stud fastener in position ready for installation;

Figure 16 is a section through the apparatus shown in Figure 15 taken on the line XVI-XVI;

Figure 17 is a view similar to that of Figure 15 showing the apparatus at a further stage in the sequence of installation;

Figure 18 is a top plan of a part of the apparatus shown in Figures 15 and 17;

Figure 19 is a section through the apparatus shown in Figure 17 taken on the line XIX-XIX;

Figure 20 is a part sectioned side view of another example of installation head apparatus in accordance with the invention;

Figure 21 is a section through part of the apparatus shown in Figure 20 taken on the line XXI-XXI;

Figure 22 is a perspective view of another part of the apparatus of Figure 20;

Figures 23 to 25 are views similar to that of Figure 20 illustrating different stages in the sequence of installation of a fastener;

Figure 26 is a part sectional side view of a stack of stud-like fasteners in accordance with the invention in a flexible transfer tube;

Figure 27 is a part sectioned and cut-away perspective view of an example of a self-attaching fastener in accordance with the invention in the form of a nut.

Figure 28 is a part sectioned side view of the self-attaching nut fastener shown in Figure 27 and part of its installation apparatus at one stage in the attachment of the nut to a panel; and,

Figure 29 is a view similar to that of Figure 28, but showing the final step of the installation.

As described above, the self-attaching fastener of this invention is particularly adapted for permanent attachment of the fastener to a plate or panel, particularly a metal sheet or the like, such as utilized in the automotive industry for component parts. The self-attaching fastener and installation apparatus of this invention is particularly suitable for installation in a conventional press, such as utilized by the automotive industry to form sheet metal parts, including body panels and the like. In such applications, the press installs one or more fasteners with each stroke of the press, wherein the fastener becomes a permanent part of the panel and is utilized to affix other structural members, such as brackets or the like to the panel. Further, as described above, the self-attaching fastener of this invention is particularly suitable for attachment to relatively thin sheets or panels, such as utilized by the automotive and appliance industries. As used herein, "panel" refers to any plate, panel or metal sheet having a thickness thin enough for the annular self-piercing and riveting wall to penetrate the panel and provide sufficient clearance for riveting attachment, as described.

Figure 1 illustrates a self-piercing and riveting bolt 10 which consists essentially of a cylindrical shank 20 having an external thread, a head portion or flange extending radially outwardly from the shank portion and an annular piercing and riveting portion 40 coaxially aligned with the shank portion and forming an extension of the shank axis on the side of the head 30 remote from the shank 20.

More specifically, the head 30 of the self-attaching bolt shown in Figure 1 is situated on the end surface opposite the free end 21 of the shank and includes an annular pressing surface 31 which surrounds the shank 20. The opposite side of the head portion includes an annular bearing surface 32 surrounding the self-piercing and riveting portion and bounded by a stamping edge 33. The free end portion 41 of the annular wall includes an opening into a central recess 43 which tapers slightly conically to a bottom wall 42. In the disclosed embodiment, the bottom wall 42 is conical and convex, extending at an angle 45 obliquely from the axis of the self-attaching bolt 10. The outer edge 42a of the conical bottom wall 42 and the bearing surface 32 lie in approximately the same plane in the disclosed embodiment. As disclosed more fully hereinbelow, the bottom wall 42 of the recess 43 of the stud type fasteners may be either convex or concave to accommodate various panel thicknesses.

The free end 41 of the annular wall 46 includes a cutting or piercing edge 47, which bounds the central recess 43, and an annular arcuate driving and drawing surface 48. The driving and drawing surface 48 is oriented generally perpendicular to the axis of the self-attaching bolt 10 and the outer surface of the free end of the annular wall includes a rounded driving and drawing surface 49 interconnecting the drawing surface 48 and the external keying wall 50. In the disclosed embodiment of the self-attaching bolt, the keying wall 50 tapers from the driving and drawing surface 49 towards the head portion 30 at a clearance angle 51 relative to the axis of the bolt 10 and blends into the bearing surface 32 of the head 30 in an arcuate surface.

Figure 2 illustrates a second embodiment of the self-attaching fastener in the form of a self-piercing and riveting screw fastener 100. The screw fastener of Figure 2 differs from the self-piercing bolt 10 of Figure 1 in that a guiding and spacing step 125 is located on the axis of the riveting screw between the end face of the threaded shank 120 and the head 130. The guiding and spacing step 125 includes an annular pressing surface 126 which surrounds the shank 120 and

includes a transition at a shoulder into an adjacent pressing surface 131 of the head 130.

The installation apparatus shown in Figure 3 includes a plunger or pressing die 60 and a female die or die button 70 having a central counter-hole die or bore 80. The pressing die or plunger 60 may be a component of a relatively complex installation system which includes an installation head, shuttle and transfer means, as described more fully hereinbelow. The pressing die or plunger includes a central recess or bore 62 which receives the shank 20 of the bolt fastener and an annular end portion 61 which engages the pressing surface 31 of the body portion of the fastener. In the disclosed embodiment of the installation apparatus, a self-piercing and riveting screw or bolt 10 as shown in Figure 1 is located ready for installation with the threaded shank 20 received in the central recess 62 and the annular pressing surface 61 of the die 60 engaging the pressing surface 31 of the bolt 10. The drawing surface 48 at the free end of the annular wall 46 bears against the panel 90. It will be noted that the panel 90 is generally perpendicular to the longitudinal axis of the self-piercing and riveting bolt 10 and the panel is supported on the seating surface 71 of the female die 70. The female die 70 includes an axial depression or concave die cavity 72 which is coaxially aligned with the annular wall 40 and the panel supporting or seating surface 71 is connected to the die cavity through a blending radius 73. The die cavity 72 includes a bottom wall 74 which, in the disclosed embodiment, is generally parallel to the seating surface 71 and includes a central cylindrical bore 75.

In the embodiment of the die assembly shown in Figure 1, a cylindrical counter-hole die 80 is telescopically located in the central die bore 75. In the embodiment of the female die assembly shown in Figure 3, one free end of the counter-hole die 80 penetrates into the die cavity 72 of the female die or die button 70 forming an annular die cavity. As shown in Figure 4, the free end of the counter-hole die 80 includes a truncated conical splaying body 81, the base 82 of which is situated at approximately the level of the bottom wall 74 of the die cavity 72 and which extends generally as far as a cylindrical cutting projection 83. This cutting projection 83 has a diameter generally equal to the internal diameter of the recess 43 of the self-piercing and riveting bolt 10 and is radially bounded at the free end and face by a cutting edge 84 which mates and cooperates with the cutting edge 47 of the self-attaching bolt 10 to pierce a slug from the panel 90. Further, the cutting projection 83 includes a central splaying cone 85 on its free end surface which prevents lateral relative movement of the panel slug upon first contact of the cone with the panel.

It will be understood that an intermediate step in the disclosed process includes inserting the self-attaching bolt 10 in the recess 62 of the die member or plunger 60 as will be described more fully hereinbelow. The plunger 60 then moves relative to the female die member 70 to pierce the panel and install the bolt fastener as illustrated in Figures 5 and 6.

As the pressing die or plunger 60 moves with the self-piercing and riveting bolt 10 relative to the female die 70 with the counter-hole die 80 and panel 90, the portion of the panel covering the depression or die cavity 72 in the female die is deformed into the die cavity by the driving and drawing surface 48 of the self-attaching bolt around the bending radius 73 and into the female cavity 72 of the female die 70. The panel is then pierced or sheared between the piercing or cutting edge 47 of the self-riveting bolt 10 and the cutting edge 84 of the counter-hole die 90, forming a slug 91, generally corresponding in diameter to the internal diameter of the recess 43 of the annular wall of the self-attaching bolt 10. The slug is punched or trepanned out of the panel by the mating piercing surfaces as shown in Figure 5. The panel slug 91, which is domed over the splaying cone 85 of the counter-hole die 80, is pushed during the further movement of the splaying cone 85 into the conicallly tapering recess 43 in the annular wall.

During continued relative movements of the self-attaching bolt 10 and the female die assembly, the annular wall 46 of the bolt 10 is pressed against the exterior wall surface of the splaying body 81 on the counter-hole die 80 and the free end of the annular wall is deformed radially outwardly in an L-shape against the bottom wall 74 of the female die cavity 72 An annular peripheral groove 52 is thus formed in the riveting wall 46 which is defined by the L-shaped riveting wall 46 and the bearing surface 32 of the fastener head 30. The portion of the panel 90 which is deformed into the female die cavity 72 is then deformed inwardly into the peripheral groove 52, forming a secure fastener and panel assembly.

Simultaneously, the slug 91 pierced from the panel is pressed by the splaying cone 85 against the convex conical bottom wall 42 of the recess 43 in the stud bolt 10. The opposed conical surfaces of the splaying cone 85 and the bottom wall 42 of the recess deform the slug 91 radially outwardly, firmly jamming the slug in the recess 43 against the inner wall. The bearing surface 32 of the body portion of the self-attaching bolt 10 is simultaneously pressed into the opposed surface of the panel 90 as shown in Figure 6. As the bearing surface 32 is pressed into the panel surface, the riveted connection of the annular wall 46 and the panel 90 is formed. In the final assembly, the annular wall 46 is located between the panel portion bearing against the annular wall and the panel slug 91, which is firmly jammed in the recess 43. The self-attaching bolt 10 is thus firmly and non rotatably mounted on the panel 90 in one continuous operation, without additional securing means or special forming operations.

The panel slug 91 thus performs an important function in the installation process and becomes an integral part of the assembly in the stud-like fasteners shown in Figures 1 and 2 having an enclosed recess 43. The slug is centered and supported on the free conical end 85 of the counter-hole die 80 and is located in the annular wall recess generally at the location of the greatest inward stress. For example, the panel slug 91 is located at the opening of the recess 43 immediately following piercing, as shown in Figure 5, thus preventing collapse of the annular wall as the pierced panel edge is deformed into the die cavity against the external surface of the annular wall, as shown. The slug is continuously moved into the

recess as the annular wall 46 is deformed radially outwardly, reinforcing the annular wall during the radial deformation of the free end of the wall. Finally, the slug is deformed against the bottom wall 42 of the recess, as shown in Figure 6, reinforcing the fastener and panel assembly and forming an integral part of the assembly, as described.

It will be understood that the shape of the annular wall 46 and the configuration of the fastener portion will be dependent upon the particular function of the fastener. For example, the annular wall 46 may be cylindrical, hexagonal, octagonal or other annular configurations. The fastening portion 20 may be threaded or unthreaded, the shank may include a ball, clevis or other fastening means or the entire configuration may be changed for a particular application.

The stud fasteners and apparatus illustrated in Figures 1 to 6 are also described in our UK Patent No. 2 068 493.

An embodiment of a self-attaching stud fastener in accordance with the present invention is illustrated in Figure 7. The stud fastener 150 includes a head or body portion 152 in the form of a radial flange, an unthreaded shank portion 152 and a self-piercing and riveting annular wall 156. The outer surface 158 of the annular wall in the disclosed embodiment is generally cylindrical and terminates in a rounded driving and drawing surface 160. The annular wall includes a central recess 162 opening through the free end of the annular wall. The inner surface 164 of the annular wall is also generally cyclindrical in the disclosed embodiment and terminates in a piercing surface 166 adjacent the free end of the annular wall. The recess 162 terminates in a bottom wall 168, which in the disclosed embodiment is conical and concave.

The top surface 170 of the head 152 provides an annular pressing surface adjacent the shank 154 of the stud and the bottom surface 172 of the head defines an annular bearing surface, as described above. The side surface 174 of the head smoothly blends into the bottom surface 172 in a rounded or arcuate surface 176 and the bottom surface 172 of the head smoothly blends into the outer surface 158 of the annular wall through a rounded or arcuate surface 178. It will be understood that "top" and "bottom" are relative terms depending upon the orientation of the stud fastener and are used herein only for descriptive purposes. As described above, the self-attaching fastener of this invention may be attached with the die member or button located either on the top or the bottom shoe of a die press, for example. Further, the annular wall 156 may be any annular configuration, including cylindrical, hexagonal, octagonal, etc. The stud fastener of Figure 7 is, however, a simplified and therefore less expensive embodiment of the self-attaching fastener of this invention as the outer and inner surfaces (158 and 164) of the annular wall are parallel.

Figure 12 illustrates a preferred embodiment of the female die member or die button 180. The die button includes a panel supporting or seating shoulder 182, a central die portion 184 projecting from an annular die cavity 186. The outer surface 188 of the die cavity is inclined or sloped inwardly from the panel supporting shoulder 182, preferably in an "e function" and the inclined outer die surface 188 blends into the panel supporting shoulder 182 in a smooth arcuate surface 190. The free end of the central projecting die portion 184 includes a convex conical surface 192, preferably including a relatively sharp apex 194. The outer edge of the central projecting die portion 184 includes a relatively sharp piercing or shearing edge 196 which is defined by an annular flat surface 198 on the free end of the central projecting die portion and a flat or cylindrical surface 200 at the upper side of the central projecting die portion. The bottom surface 202 of the annular die cavity is semi-tordoidal and terminates in an annular lip 204 adjacent the inclined or sloping outer surface 188. The annular lip 204 blends into the bottom surface 202 and the outer sloping die surface 188 through arcuate die surfaces.

Figures 8 to 11 and 14 illustrate the preferred installation sequence of the stud fastener of Figure 7 in the die button of Figure 12 and a preferred embodiment of the method of installing the self-attaching fastener of this invention. As described above, the stud fastener 150 is first oriented relative to the panel 206 to which the fastener is to be installed with the self-piercing and riveting annular wall 156 facing the panel. The axis of the stud fastener is generally perpendicular to the plane of the panel 206. In the disclosed embodiment of the installation apparatus shown in Figures 8 to 11 and 14, the stud fastener 150 is driven into the panel by a pressing die or plunger 210 which has an axial recess or bore 212 which receives the shank 154 of the stud fastener. The plunger includes an annular driving or pressing surface 214 which bears against the annular pressing surface 170 of the fastener head 152. The stud fastener is then driven into the panel by relatively moving the plunger 210 and the die button 180, as will now be described.

As shown in Figure 8, the panel 206 is first deformed into the die cavity 186. The panel is first engaged by the rounded driving and drawing surface 160 at the free end of the annular wall 156 as described above. The panel portion located inside the annular wall 156 is then domed or trepanned against the conical surface 192 of the free end of the central projecting die portion 184, fixing this portion of the panel prior to piercing or shearing, as will now be described.

The panel is then pierced or sheared as shown in Figure 9. The panel is sheared between the shearing or piercing surface 166, adjacent the free end of the fastener annular wall 156, and the piercing edge 196 at the outer edge of the projecting central die portion 184, forming a panel slug 216 which is diposed within the fastener annular wall recess 162 on the conical free end of the projecting die portion 184. It will be understood that the configuration of the die button piercing edge 196 (i.e. circular, hexagonal, octagonal, etc.) should be the same as the annular wall 156, such that the piercing surfaces mate to shear or pierce the panel. The piercing surface 166 of the annular wall 156 is preferably a chamfer face inclined outwardly from the axis of the annular wall recess 162. The shearing of the panel then occurs along the shearing face 166, forming a panel slug 216 having an external diameter slightly greater than the internal diameter of the inner face 164 of the annular wall, providing an interference

fit. The including shearing face 166 is "self-corrrecting" and assures a clean shearing of the panel with a minimum of force. The elimination of a sharp cutting edge on the annular wall also reduces splitting of the free end of the annular wall and the pierced panel edge during the final installation, as will be described hereinbelow.

As shown in Figure 10, the continued relative movement of the self-attaching stud fastener 150 and the die member 180 results in the engagement of the free end of the annular wall 156 against the semi-toroidal arcuate bottom surface 202 of the die cavity, simultaneously drawing the portion of the main panel adjacent the pierced panel edge 218 against the external surface 158 of the annular wall 156. It should be noted again that the panel slug 216 is thus located at the point of greatest stress in the annular wall, just beyond the point of contact between the free end of the annular wall 156 and the concave semi-toroidal bottom surface 202 of the annular die cavity. The panel slug thus prevents inward collapse of the annular wall during the installation. Continued relative movements of the stud fastener 150 and the die button 180 deforms the free end of the annular wall radially outwardly against the arcuate surface 202 of the die cavity, forming a hook or U-shaped channel in the cross-section at the free end of the annular wall, as shown in Figure 11.

The panel portion adjacent the pierced panel edge 218 is then trapped between the hooked end 156a at the free end of the annular wall 156 and the head portion 152 of the stud fastener as the radial surface 176 of the head is driven into the panel. It should be noted that the panel slug 216 has been moved into the annular wall recess 162 and is again located at the point of greatest stress on the annular wall. It should be also noted that the conical surface 192 of the central projecting die portion 184 has prevented any lateral movement of the panel slug 216 in the annular wall recess which would adversely affect the forming of the mechanical interlock between the panel and the fastener annular wall. Continued relative movement between the stud fastener 150 and the die button 180 causes counter rotation of the panel portion 218 adjacent the pierced panel edge in the channel defined by the stud fastener head portion 152 and the radially outwardly deforming annular wall free end 156a, as best shown in Figure 14.

Figure 14 illustrates the final configuration of the stud fastener and panel assembly of this invention. The annular wall 156 now includes a first tubular portion 156d and a second radially outwardly hook-shaped end portion 156c. The slub 216, which was pierced from the main portion of the panel 206, has been deformed against the bottom wall surface 168 of the recess by the conical free end 192 of the central projecting die portion 184. The deformation of the panel slug against the bottom surface 168 of the recess deforms the slug radially outwardly into firm binding contact with the inner surface 164 of the recess, such that the panel slug becomes an integral part of the fastener and panel assembly.

The panel 206 now includes a main portion bearing against the panel supporting shoulder 182, a second portion 206a displaced from the plane of the main panel and bearing against the inclined outer wall 188 of the die cavity and the annular lip 204, which has limited the deformation of the panel into the die cavity and which supported the panel during the final deformation of the panel in the hook-shaped end portion 156a of the annular wall. As described, the panel portion immediately adjacent the pierced panel edge is counter rotated between the bottom surface 172 of the fastener head portion 152 and the hook-shaped end portion 156a of the annular wall, resulting in an enlarged annular bead 218a which is securely trapped in the hook-shaped end portion 156a of the annular wall. The annular bead 218a further reinforces the assembly. Finally, the fastener head portion 152 has been driven into the panel, as described, such that the top surface 170 is generally parallel to the adjacent surface of the main portion of the panel 206, resulting in a flush mounting, which is particularly advantageous in many applications where a second structural member, such as a panel, is attached to the shank portion 154 of the stud fastener. It should also be noted that the piercing or shearing edge 166 has been deformed and rotated, and is now located at the outer extremity of the hook-shaped annular wall portion 156a, preventing splitting of the panel or the riveting end of the fastener.

The resultant fastener and panel assembly shown in Figure 14 is extremely strong and rigid, which is particularly important in a stud-like fastener assembly having a shank portion extending from the plane of the panel 206. The push-through or pull-out strength of the assembly is actually greater than the strength of the stud shank 154, in most applications. The pull-out strength is measured by pulling the stud shank 154 in the same direction as the stud fastener was installed, against the panel. The push-through strength of the assembly is measured by pushing the stud fastener through the panel. Anti-rotation means may also be included in the die assembly, such as shown in Figure 13, wherein the torque strength of the assembly is as great as the stud. In the embodiment of the die button 180 shown in Figure 13, three flats 220 are provided on the outer inclined wall 188. The flats 220 in the disclosed embodiment are generally parallel to the axis of the conical free end 192 of the central die portion and the flats extend from the annular lip 204 to the bearing surface 182 of the die button. The flats deform the panel draw and very slightly deform the stud flange, providing excellent anti-rotation means.

As used herein, a piercing or shearing "surface" includes a relatively sharp piercing edge, such as the sharp piercing edge 47 of the self-attaching bolt shown in Figure 1 and the piercing chamfer face 166 on the self-attaching stud shown in in Figure 7. A sharp piercing edge may be preferred in certain applications where the panel slug is finally removed from assembly, such as the self-piercing nut shown in Figures 27 to 29. A chamfered piercing face is, however, preferred where the panel slug becomes an integral part of the fastener and panel assembly, as described above in regard to the stud fastener of Figure 7. The installation apparatus described to this point includes a die button and a simple pressing tool or plunger which may be utilized in low production. The fastener may be simply inserted in the plunger and the plunger

is driven toward the die button to install the fastener. In mass production, however, the self-attaching fasteners must be fed to the plunger and automatically oriented and aligned for installation. The automatic feeding, alignment and installation of stud-like fasteners having a projecting shank portion, however, presents unique problems because the fastener must be very accurately aligned with the die button prior to each installation. Two alternative installation heads particularly adapted for feeding and installing stud-like fasteners will now be described.

The installation head apparatus 250 shown in Figures 15 to 19, is particularly although not exclusively adapted for installing self-attaching stud-like fasteners, such as the self-attaching bolt, screw and stud fasteners shown in Figures 1, 2 and 7. As described, the stud-like fasteners 300 include a head or body portion 312, a threaded or unthreaded shank portion 370 and a self-piercing and riveting annular wall or skirt portion 374. This type of fastener must be accurately oriented and aligned relative to the plunger or pressing member and the die button, not shown. The die button will normally be fixed relative to the stationary die member or shoe and the installation head apparatus is normally fixed to the moveable die shoe. As described, however, this arrangement may be reversed.

The installation head 250 shown in Figure 15 includes a base member 252 and a relatively moveable nose assembly 254. The base member 252 is attached in the disclosed embodiment to the upper moveable die shoe 256 by a back-up plate 258. The plunger 260, which is cylindrical in the disclosed embodiment, is fixed to the base member 252 by a transverse pin 262, or other suitable means. The relative movement between the base member 252 and the nose assembly 254 is controlled by a piston assembly 264, which in the disclosed embodiment is a double acting pneumatic piston. The piston assembly 264 includes a cylinder 266, which is fixed in the base member 252 by a radial flange 268 retained between the member 252 and the back-up plate 258. The cylinder 266 includes an internal O-ring 272, which seals the lower end of the piston chamber. The piston assembly includes a piston head 274 having a conventional sealing ring 276 and the piston includes a rod end 278 having a threaded end portion 280 which is threadably received in the magazine plate 282 of the nose assembly. A lock nut 284 prevents unthreading of the rod end 278 from the magazine plate 282.

The magazine plate 282 of the nose assembly 254 includes a cylindrical plunger passage 286 which telescopically receives the plunger 260 during installation of the self-attaching stud fasteners, as described hereinbelow. The magazine plate 282 also includes a guide bushing 288, which slideably receives the plunger 260, such as a conventional brass bushing which is secured to the magazine plate by a stop ring 290. The stop ring 290 also limits the relative movement of the nose assembly 254 and the base member 252. In the disclosed embodiment, the stop ring 290 is a steel ring which is press fitted over the brass guide bushing 288. Self-attaching fasteners 300 are received through a flexible tube, as described hereinbelow, through a conventional tube coupling 292, which may be a conventional quick connect coupling. The magazine plate 282 includes a first passage 294 which receives the self-attaching fasteners 300 from the flexible tube, and a second downwardly angled passage 296, which is transverse to the plunger passage 286 and which communicates with the plunger passage to transfer self-attaching fasteners 300 from a source of fasteners, such as a hopper, through the tube coupling 292 into the plunger passage under gravity.

The self-attaching stud-like fasteners 300 are then received in a conical opening or recess 304 in the nose 302 which is attached to the magazine plate 282 by screws or other conventional fasteners. The conical opening 304 is provided by two spring biased slide members 306, each having a semi-conical surface 304a as shown in Figure 18. The slide members 306 are each spring biased in the disclosed embodiment by a coil spring 308, which is spring biased at one end against the slide member and against a snap ring 310 at its opposite end. The coil springs normally close the slide members 306 to retain a stud-like fastener 300 as shown in Figures 15 and 18. As shown in Figures 16 and 19, screws 309 are threaded into the sides of the nose 302, between the slide members which aid in locating the slide members. The nose 302 also includes a cylindrical opening 312 which is coaxially aligned and communicates with the conical opening 304 in the slide members and the plunger passage 286 in the magazine plate.

The magazine plate 282 includes a guide post 314 which is fixed relative to the magazine plate by a pin or the like, not shown, and which includes an end 316 telescopically receivable in a cylindrical opening or bore 318 in the upper die shoe 256. A pneumatic line coupling 320 is threadably attached to the back-up plate 258 and the back-up plate includes a pneumatic passage line 322 which communicates through the back-up plate with the piston chamber 323 in cylinder 266. Pneumatic line coupling 324, which is threadably attached to the magazine plate 282, communicates through pneumatic passage line 326 with the rod end 278 of the piston. The piston rod 278 includes an axial passage 328 for relatively closing the base member and nose assembly, as described hereinbelow.

The back-up plate 258 also includes a pneumatic sensing line or passage 330 which communicates through line 332 with the actuation means of the die press assembly. Pneumatic line 332 is connected to the back-up plate by coupling 334. Self-attaching fasteners 300 are fed from the first fastener passage 294 to the conical opening 304 by timed pneumatic pressure through pneumatic line 336. Pneumatic line 336 communicates with the first fastener passage 294 through angled passage 338. When a fastener is located in the position shown at 300a, a burst of pressure through line 336 and passage 338 will propel a fastener located at 300a to the conical opening 304, ready for installation. The stop mechanism 342, however, prevents entry of a fastener to the ready position shown at 300a until the fastener located in the conical opening 304 has been installed. The stop mechanism includes a stop plate or bracket 344 which is secured to the base member 252 by a screw 346 or other fastening means. The stop mechanism includes

two spaced stop plates 348 secured to the bracket 344. The stop plates 348 each include key hole slots which permit one fastener to reach the position shown at 300a only when the installation head apparatus is opened to the position shown in Figure 15, as will be described more fully in regard to Figures 20 to 25.

Figure 16 shows the details of the plunger assembly. As shown, the plunger 260 includes an axial bore 350 which telescopically receives the shank portion 370 of the self-attaching stud fastener and an annular end portion 352 which bearingly engages the head or body portion 372 of the fastener. As described above, the fastener also includes a self-piercing and riveting annular wall or skirt portion 374.

As best shown in Figure 16, the axial bore 350 at the free end of the plunger 260 communicates with a second smaller axial bore 355 which receives a first pin 356 having a head portion 358 telescopically disposed in a slightly larger bore 359. A second cylindrical pin 360 is telescopically received in longitudinal bore 359 and supported on the head 358 of the first pin 356. As shown, the end of the first pin 356 opposite the head 358 is disposed in the bore 350 in the end of the plunger, such that the pins 356 and 360 are moved upwardly in Figure 16 when the shank 370 of a stud fastener is disposed in bore 350, as shown in Figure 19. The assembly also includes a proximity switch 362 having a wire 364 to the control of the actuation means as described below.

As best shown in Figure 15, the double acting piston 264 includes an internal piston 380 reciprocable in internal chamber 382 having an O-ring seal 384 and a ring bearing 386. The external piston head 274 also includes a series of ports 388 which provide communication between chamber 323 and the chamber defined between internal piston head 380 and ring seal 386. Pressure is continuously provided through pneumatic line 320 and passage 322 to piston chamber 323. In the open position shown in Figure 15, pneumatic pressure is also supplied through passage 326 in the magazine plate 282 and through the axial passage 328 in the rod end 278 of the piston into chamber 382. Pressure in chamber 382 bears against the internal piston head 380, extending the piston assembly as shown in Figure 15. When the pressure in passage 326 is removed, however, the pressure in chamber 323 is communicated through ports 388, moving piston head 380 upwardly to relatively close the nose assembly 254 toward the base member 252, as shown in Figure 17. The operation of the installation head apparatus shown in Figures 15 to 19 may now be described.

The double action pneumatic piston assembly 264 opens and closes the assembly, as described, and serves as a spring means. Upon opening of the die press assembly following installation of a stud fastener, the base member 252 and nose assembly 254 are spaced, as shown in Figure 15 by pressurizing both of passages 322 and 326. A stud fastener is then located in the position shown in phantom at 300a and a burst of pressure through pneumatic line 340 transfers the stud fastener to the conical opening 304, as described above, where the fastener is automatically centered and oriented in the conical opening. As shown in Figure 15, the conical opening receives the self-piercing and riveting annular wall 374 of the fastener and the fastener is normally oriented with the shank portion coaxially aligned with the axis of the plunger 260.

The control mechanism of the installation head apparatus then stops supplying pressure to passage 326, which relatively closes the nose assembly 254 toward base member 252 as shown in Figures 17 and 19, and described above. In this position, the free end of the stud fastener shank 370 is disposed in the axial bore 350 in the end of the plunger 260 against the end of the first pin 356. The first pin 356 and the second pin 360 is thus raised upwardly in Figure 19 to close proximity switch 362. The closing of the proximity switch 362 thus assures that a stud fastener is located in the conical opening 304 of the nose 302 and the stud fastener is accurately oriented and aligned with the plunger ready for installation. As described above, any misalignment of the stud fastener may damage the installation apparatus, requiring down time and substantial repair of the assembly. Further, as described, the actuation of the proximity switch assures that a fastener is located in the nose assembly, ready for installation.

The final installation of the stud fastener follows the actuation of the die press assembly by pneumatic sensing line 330, wherein the upper die shoe 256 is moved toward the lower die shoe, not shown. As described above, the lower die shoe includes the die button as shown in Figure 3, or more preferably, as shown in Figure 12. As described, the die member 180 (Figure 12) is fixed relative to the lower die shoe with the central projecting die portion 184 in coaxial alignment with the plunger passage 286 and telescopically receivable in the self-piercing and riveting annular wall 374 of the fastener. When the nose assembly engages the panel, the movement of the nose assembly 254 stops and the plunger 260 moves relative to the nose assembly to first engage the annular end 352 (Fig. 19) of the plunger against the head 372 of the stud fastener. The fastener is then driven through the nose assembly, spreading slide members 306 against springs 308, installing a fastener in a panel located on the die button as shown in the sequence of Figures 7 to 11 and 14.

Figures 20 to 25 illustrate an alternative embodiment of the installation head apparatus particularly suitable for installing self-attaching stud-like fasteners. As defined above, "stud fasteners" is intended to be generic to any self-attaching fastener of this invention having a projecting end portion, including threaded bolts, screws, studs having an unthreaded shank portion, and similar fasteners, including ball fasteners and the like.

Referring now to Figure 20, the disclosed installation head apparatus 400 includes a plunger assembly 402 and a shuttle-feed assembly 404. The plunger assembly includes an upper plunger 406, which is fixed relative to an upper die shoe platen 408. The upper plunger 406 reciprocates in a cylindrical guide cartridge 410 having a chamber 432, and includes a piston head 412 which is sealed relative to the inner wall of the cylinder guide cartridge by an O-ring seal 414, or the like. The piston head 412 is attached to the intermediate portion 418 of the upper plunger by a

retaining ring 416. The upper plunger also includes an annular lower end portion 420 which receives the split lower plunger assembly 442, as described hereinbelow.

An internal piston 422 is reciprocably disposed in an axial cylindrical bore 424 in the upper plunger 406. The internal piston 422 includes a head portion 426 and an annular bearing 428 which are sealed within the chamber 424 by O-ring seals or the like. The upper piston head 412 reciprocates in a cylindrical chamber 432 in the cylindrical guide cartridge 410 and the upper end of the cylindrical guide cartridge includes a snap ring 434 and spacer 436 limiting upward movement of the upper plunger 406. An O-ring seal 438 is also provided at the lower end of the cylinder die cartridge 410, which seals against the annular lower end portion 412 of the upper plunger. The cylinder guide cartridge 410 is fixed at its lower end to a movable stripper plate 440 by many suitable means including dowel pins or the like. As described, the annular lower end portion 420 of the upper plunger 406 receives the split lower plunger assembly 442. The lower plunger assembly includes a first lower movable plunger member 444 and a mating second plunger member 446 which includes an upper annular end portion 448 which is normally spaced from the lower plunger member 444, as shown in Figure 20, and the rod end 450 of the internal piston 422 engages the top of the annular end 448 of the first lower plunger member 444. A stop pin 452 and stop ring 454 limits upward axial movement of the second plunger member 446, as will be described hereinbelow. The lower end of the split lower plunger assembly reciprocates in the plunger passage 458 of the installation head of the nose 456.

Pneumatic pressure, which opens the plunger assembly 402, is received through pneumatic pressure line 460, which is attached to the cylinder guide cartridge 410 by a conventional pneumatic fitting 462, such that pneumatic line 460 communicates with the chamber 432 in the cylinder guide cartridge 410 and the chamber 464 in the upper plunger 406 through passages 465 and 467. The internal chamber 464 is sealed by a plug 466. The plunger assembly 402 is normally spaced in the open position shown in Figure 20 when the die press is opened by coil spring 468 or any other suitable spring means.

Self-attaching stud fasteners 300 are fed to the shuttle-feed assembly 404 through flexible tube 470. As described above, the stud fasteners each include a projecting shank portion 370, a head or body portion 372 and a self-piercing and riveting annular wall or skirt portion 374. The stud fasteners are first received in a tube adapter 472 having a bore or chamber 474 which initially receives the fasteners. The stop assembly 476 then transfers the stud fasteners one at a time to the shuttle mechanism. As best shown in Figure 22, the stop assembly includes an upper plate 478 having a key hole slot 480. The end opening to the key hole slot includes a beveled edge 482, preventing jamming of the fastener, as described below. The stop assembly also includes a lower block member 484 having a lower projecting plate portion 486 extending generally parallel to the upper plate 478. The upper plate is attached to the lower block member by screws 488 or other suitable fastening means. It will be understood that the head portion 372 of the stud fasteners will pass through the enlarged opening of the key hole slot 480, but the lower plate portion 486 is located opposite the enlarged opening.

The stud bolts 300 are fed to the plunger by a shuttle, including a shuttle block 490 having a conventional pneumatic piston 492. Pneumatic piston 492 includes a threaded nipple 494 threadably attached to the shuttle block 490. Pneumatic pressure line 496 is attached to and communicates with the pneumatic piston 492 to extend and retract the piston rod 498. The piston rod 498 includes a threaded end 500 which is threadably attached to the shuttle 502 and secured by a nut 504. A coil spring 506 is received in opposed bore openings 508 and 510 in the shuttle block 490 and the lower block member 484 of the stop assembly, respectively. The coil spring 506 normally spring biases the stop assembly to the left in Figure 20, however stop pin 512 in shuttle 502 prevents lateral movement of the stop assembly until the shuttle 502 is extended, as described below.

The movement of the shuttle 502 is guided in the disclosed embodiment by a shuttle guide 520 having a rail 522 and a stop tab 524 extending from the bottom of the shuttle guide. The shuttle guide 520 is attached to a stop plate 526 by any suitable means, including screws. The stop plate includes a slot or groove 528 which receives the end of the lower projecting plate 486 of the stop assembly 476. The stop plate 526 is attached to support plate 530 and the support plate is attached to the stripper plate 440. As shown in Figure 20, the end of the upper plate 478 of the stop assembly is received on top of the support plate 530.

Figure 21 illustrates certain details of the nose and split lower plunger assembly. As shown, the first lower plunger member 444 includes one or more small rod magnets 532 which securely but releasably retain the shank 370 of the stud fastener upon receipt of the stud fastener in the first lower plunger member. Spring biased balls 534 press the shank portion of the stud fastener against the magnets. The balls are spring biased by small coil springs 536, which are retained by screws or plugs 538. As a further assurance of location and orientation of a stud fastener ready for installation, a conventional photo-reflection sensing means 540 (Fig. 20) may be provided in the plunger passage.

Having described the elements of the installation head apparatus of Figures 20 to 25, it is now possible to describe the operation. As set forth above, Figure 20 illustrates the installation head when the die press is fully opened, following the installation of a self-attaching fastener. The installation head is "opened" as shown in Figure 20 by actuating pneumatic pressure line 460, which transmits pressure to chamber 432 and chamber 464 through passages 465 and 467. Chamber 464 has the greater volume, extending plunger 406. Stop pin 452 then engages stop ring 454, limiting upward movement of the assembly. A stud fastener is then located in the shuttle 502. The stud fastener previously in the split plunger assembly 442 has been installed in a panel and the panel has been removed. As described above, a female die is located on the lower stationary die member, not shown, with the center projecting die portion coaxially aligned with

the plunger. It is very important that the die button be securely retained on the die member opposite the installation head apparatus. A panel is then inserted in the die press over the die button, ready for receipt of a self-attaching fastener. In most applications, the panel will also be fixed relative to the stationary die member to prevent any movement of the panel during the installation of the self-attaching fastener. Further, as described above, the panel may be formed in the die press simultaneously with the installation of the self-attaching fastener. The forming of the panel may be accomplished in a single stroke, or a progressive die may be utilized.

The shuttle piston 492 is first actuated by actuating pneumatic line 496. The piston moves the shuttle 502 to the left in Figure 20, moving a stud fastener 300 from the position shown in Figure 20 to the position shown in Figure 23. The shuttle 502 forces the shank 370 of the fastener past the ball detents 534 (see Figure 21) into engagement with the rod magnets 532. The movement of the shuttle 502 is limited by stop 524, as shown in Figure 23. The movement of the shuttle also releases the stop assembly 476 which had been retained by stop pin 512, as shown in Figure 20. The stop assembly 476 is then biased by spring 506 to the left, as shown in Figure 23, releasing a stud fastener from the position shown at 300a in Figure 20, through the enlarged opening of the key hole slot 480 and against the lower projecting plate portion 486 of the stop assembly, as shown in Figure 23. As described above, a photoreflection sensing means 540 may be utilized to assure the location of a fastener in the first lower plunger member 444, ready for installation. The die press is then actuated, lowering the upper platen 408, which closes the split plunger assembly as shown in Figure 24. The upper plunger 406 is thereby pressed into the cylindrical cartridge guide 410 which presses against the upper annular portion 418 of the second lower plunger member 446, closing the split plunger assembly and closing the axial bore 542 in the end of the lower plunger as shown in Figure 24. As described above, the plunger includes an annular end portion 544, which bears against the head or body portion 372 of the stud fastener, which is retained in place by the rod magnets 532. It is noted that the shuttle 502 is simultaneously retracted by piston 492, such that the next stud fastener is ready for installation upon completion of the sequence. The plunger assembly is now interlocked to act as an integral unit and the stud fastener is now ready for installation as shown in Figure 25.

In the final installation, the upper die show platen 408 engages the upper plunger 406, driving the self-piercing and riveting wall 374 into a panel 560 located on the die button 562, as shown in Figure 25. The shuttle is now fully retracted and a stud fastener is dropped into the shuttle, as shown. It should be noted that the plunger assembly 402 thus serves as an air spring, damping the assembly. Upon opening of the die press, the assembly is returned to the position shown in Figure 20 by the plunger assembly and coil spring 468 and a fastener is now located in the shuttle, ready to repeat the sequence described hereinabove.

Figure 26 illustrates the unique stacking feature of the self-piercing studs 300 of this invention. As described above in regard to the feeding of the self-piercing studs to the installation head apparatus disclosed in Figures 15 to 25, the studs may be fed to the installation heads 250 or 400 through a flexible tube under pneumatic pressure. For ease of reference, the stack of stud fasteners 570 is shown feeding the installation head shown in Figures 20 to 24, however, it will be understood that the same relationship exists with the installation head apparatus disclosed in Figures 15 to 19.

As described above, the stud fasteners 300 are preferably fed to the installation head through a flexible tube 470. In the embodiment of the installation head shown in Figures 20 to 25, the fasteners are fed to a tube adapter 472. Each stud fastener includes a tube-shaped self-piercing and riveting annular wall or skirt portion 374, a head or body portion 372 and a shank portion 370. In the preferred embodiment, the tubular annular wall 374 has an internal diameter greater than the diameter of the shank portion 370 and the length of the shank portion 370 is greater than the depth of the recess in the tubular head portion 372, such that a "flexible" stack of fasteners 570 is formed capable of being fed through a flexible tube 470, as described. It will be understood that the flexible tube 470 communicates with a source of stud fasteners, such as a conventional hopper and that the fasteners are fed into the tube under pneumatic pressure. The stacking feature of the stud fasteners of this invention facilitates mass production of the installation of the fasteners in an installation head apparatus, as described.

Figures 27 to 29 illustrate a further embodiment of the self-attaching fastener of this invention, in the form of a nut fastener 600. The disclosed embodiment of the nut fastener 600 includes a head or body portion 602 having a threaded bore 604 and a self-piercing and riveting annular wall or skirt portion 606. The annular skirt portion includes a free end having a rounded driving and drawing surface 608 and a piercing surface 610 at the inner edge of the annular wall as described above in regard to Figures 1 and 2. The annular wall 606 is preferably joined to the body portion 602 spaced inwardly from the outer surface 612 in an arcuate surface 614, thereby defining an annular bearing surface 616. Further, the outer edge of the body portion 618 adjacent the annular bearing surface 616, is preferably arcuate for the reasons given hereinabove. The opposed end of the body portion includes an annular pressing or driving surface 620 for driving the fastener into a panel, as described hereinbelow. The internal surface 622 of the annular wall is preferably smooth, as described hereinabove.

Figures 28 and 29 illustrate one method of installing the self-attaching nut fastener 600 of Figure 27. As will be understood from the description of Figures 5, 6, 8 to 11 and 14, above, the installation apparatus includes a pressing die or plunger 630 and a female die 632. The female die 632 preferably includes a semi-toroidal die cavity 634 and a separate counter-hole die 636. The counter die 636 is telescopically received in a bore 638, which is coaxially aligned with the axis of the semi-toroidal die cavity 634. The pressing die or plunger 630 includes an annular end surface 640, which engages the annular pressing surface 620 of the

nut, and a ram or plunger 642 which is telescopically received in an axial bore 644 in the pressing die 630.

As described above in regard to the stud-like fasteners, the nut fastener 600 is first located opposite a panel 650 with the self-piercing and riveting wall 606 coaxially aligned with the die cavity 634. The annular wall 606 is then driven into the panel and the die cavity to pierce a slug 652 from the panel. The slug 652 is centred upon the conical projecting end portion 654 of the counter-hole die member 636. The panel slug 652 is then disposed into the recess 622 in the annular wall and the free end of the annular wall is deformed in the die cavity 636 to form a mechanical interlock between the panel portion adjacent the pierced panel edge 656 and the preferably hook or U-shaped annular wall, as shown in Figure 28. As described above, the panel slug is located on the counter-hole die at the point of greatest stress, thereby preventing collapse of the annular wall 606 during the radial outward deformation of the annular wall. The nut and panel assembly is now complete, however the panel slug 652 must be removed to permit use of the permanently installed nut 600. This is accomplished by driving the ram or plunger 642 of the pressing member through the threaded bore 604 of the nut, driving the panel slug 652 out of the annular wall recess. It will be understood that the panel slug may be driven out of the recess by counter-hole die 636 if the threads 604 are recessed from the internal surface 622 of the annular wall.

The method of installing the self-attaching nut fastener 600 may thus be the same as the methods of installing the stud fasteners described hereinabove, except that the panel slug is driven out of the annular wall recess following completion of the nut fastener and panel assembly. Further, various anti-rotation means may be provided, including flats on the internal surface of the die cavity 634 or the bearing surface 622 may include ribs or indents preventing rotation. Where anti-rotation means are provided on the bearing surface 616, the body portion is preferably driven into the panel, as shown in Figure 29.

The nut fastener and apparatus illustrated in Figures 27 to 29 are also described and shown in our co-pending Application No. 8432237 which has the same date as the present Application.

Having described the preferred embodiments of the self-attaching fastener, method of installation an installation apparatus of this invention, it will be understood that various modifications may be made within the purview of the appended Claims. The dimensions of the self-attaching fastener, for example, will depend upon the particular application and panel thickness. As described above, the self-attaching fastener of this invention is particularly adapted for permanent attachment to relatively thin panels, such as utilized for structural components in the automotive and appliance industries. For example, an M5 self-attaching bolt having a thread diameter of 0.1968 inches may be attached to panels having a thickness of 0.0315 to 0.0591 inches, providing a relatively rigid installation. An M10 self-attaching bolt having a thread diameter of 0.3937 inches is suitable for attachment in panels having a thickness ranging from 0.0394 to 0.0984 inches or 1 to 2.5 millimeters.

Further, as described above, the bottom wall of the stud fastener recess is preferably conical and convex as shown in Figures 1 and 3 to 6 where the panel is relatively thin in the ranges given hereinabove to assure that the panel slug is deformed radially outwardly into engagement with the inner surface of the annular wall. Where the panel is relatively thick, the bottom surface of the annular wall cavity is preferably conical and concave as shown in Figures 7 to 11 and 14, assuring complete installation and avoiding damage to the die button. The self-attaching fasteners may be formed of any suitable material, preferably, steel, such as the materials presently used for manufacturing conventional studs, bolts, screws and nuts. A suitable material for the self-attaching fasteners of this invention is typically medium carbon steels, including SAE 1022, 1023 and 1030 steels.

CLAIMS

1. A method of attaching a fastener to a panel, the fastener comprising a body portion and a self-piercing and riveting annular wall which extends from the body portion and which has an open free end having a piercing surface adjacent the inner surface of the wall and an arcuate surface adjacent the outer surface of the wall, the method comprising:—

a) locating the fastener opposite the panel with the free end of the annular wall facing the panel and a die member located on the opposite side of the panel, the die member having an annular concave die cavity surrounding a projecting central die portion which is coaxially aligned with and receivable within the open end of the wall;

b) engaging the panel with the free end of the annular wall so that the arcuate surface of the free end deforms the panel into the annular concave die cavity and the piercing surface pierces a slug from the panel, the central die portion supporting and centering the panel slug and carrying the slug into the space surrounded by the wall;

c) deforming the free end of the annular wall radially outwardly in the concave annular die cavity so that the free end forms an annular channel which is generally U-shaped in cross-section and which opens towards the body portion of the fastener and the pierced edge of the panel; and,

d) deforming the pierced edge of the panel against the outer surface of the annular wall into the generally U-shaped channel, forming a mechanical interlock between the panel and the self-piercing and riveting annular wall of the fastener.

2. A method according to Claim 1, in which the slug pierced from the panel has a width greater than the internal diameter of the annular wall and the slug is forced by the central die portion through the open end of the wall into engagement with the inner surface of the wall.

3. A method according to Claim 2, in which the panel slug is supported by the central die portion in binding engagement with the inner surface of the annular wall during the deformation of the free end of the wall, the panel slug bracing the annular wall and preventing collapse of the wall during the radial outward deformation.

4. A method according to any one of Claims 1 to 3, in which the free end of the projecting central die

portion is conical and has a relatively sharp apex, whereby the panel slug is deformed and domed on the conical end of the central die portion and the slug is thereby centred and retained within the annular wall.

5. A method according to Claim 1, in which the piercing surface comprises an annular chamfer face angled to the inner surface of the annular wall so that the slug pierced from the panel has a diameter greater than the internal diameter of the annular wall, and the slug is forced by the central die portion into and supported within the space bounded by the annular wall generally at the position of greatest internal stress resulting from the radial outward deformation of the annular wall.

6. A method according to any one of the preceding Claims, in which the body portion of the fastener includes a base portion having a side surface and a bottom surface which are joined by an arcuate surface, the annular wall being integrally joined to the bottom surface of the base portion inwardly from the side surface, and the base portion of the fastener is driven into the panel following the piercing of the slug from the panel, simultaneously deforming the free end of the wall radially outwardly to form the generally U-shaped channel and deforming the panel adjacent the pierced edge by counter rotating the edge portion within the channel to form a mechanical interlock in which the panel portion substantially fills the channel.

7. A method according to Claim 1, in which the panel portion adjacent the pierced edge is driven into the annular U-shaped channel, deforming the pierced edge in the U-shaped channel and forming a reinforcing enlarged annular bead enclosed within and contacting the inner surface of the U-shaped channel.

8. A method according to Claim 7, in which the body portion of the fastener includes a radial flange extending outwardly generally perpendicular to and adjacent the annular wall, and the flange portion of the fastener is driven into the panel, thereby recessing this portion of the body in the panel and driving the pierced edge portion of the panel into the U-shaped channel.

9. A method according to any one of the preceding Claims, in which the fastener is a female fastener having a bore extending through it, and the panel slug is driven out of the space bounded by the annular wall after the attachment of the fastener to the panel.

10. A method according to any one of the preceding Claims, in which the die member includes a plurality of flats on the outer periphery of the concave die cavity, and the portion of the panel adjacent the pierced edge is deformed within the die cavity, being compressed radially inwardly by die member flats to provide anti-rotation means for preventing rotation of the fastener relative to the panel following the attachment.

11. A method of attaching a fastener to a panel, the fastener comprising a body portion and a self-piercing and riveting annular wall which extends from the body portion and which has inner and outer surfaces and an open free end portion having a piercing surface adjacent the inner surface, the method comprising:—

a) locating the fastener opposite the panel with the free end of the annular wall facing the panel and a die member located on the opposite side of the panel, the die member having a concave die cavity surrounding a projecting central die portion which has a generally conical free end portion coaxially aligned with and receivable within the space bounded by the annular wall;

b) engaging the free end of the annular wall against the panel and deforming the panel against the conical free end portion of the central die portion;

c) piercing the panel with the piercing surface of the annular wall producing a slug having a diameter greater than the inner surface of the annular wall;

d) forcing the panel slug into the space bounded by the annular wall in firm engagement with the inner surface of the wall; and,

e) deforming the free end portion of the annular wall radially outwardly in the die cavity and deforming the pierced edge of the panel against the outer surface of the wall into engagement with the deformed free end portion of the wall, thereby forming a mechanical interlock between the annular wall of the fastener and the pierced edge of the panel.

12. A method according to Claim 11, in which the piercing surface comprises an annular chamfer face which is outwardly inclined from the inner surface of the wall to the free end.

13. A method according to Claim 11 or Claim 12, in which the free end portion of the wall is deformed in the concave die cavity into a U-shaped channel opening towards the body portion of the fastener, and the pierced panel edge is deformed into the U-shaped channel to form the mechanical interlock.

14. A method acording to Claim 13, in which the pierced panel edge is driven into the U-shaped channel and the free end of the pierced panel edge is deformed in the U-shaped channel to form a reinforcing enlarged annular bead on the pierced panel edge.

15. A method of attaching a fastener to a panel, the fastener comprising a body portion and a self-piercing and riveting annular wall which extends from the body portion and which has inner and outer surfaces and an open free end portion having a piercing surface adjacent the inner surface, the method comprising:—

a) locating the fastener opposite the panel with the free end of the annular wall facing the panel and a die member located on the opposite side of the panel;

b) piercing a slug from the panel with the piercing surface of the annular wall;

c) carrying the pierced panel slug into the space bounded by the annular wall on the die member;

d) deforming the free end portion of the annular wall radially outwardly to form a generally U-shaped channel opening towards the body portion of the fastener and the pierced edge of the panel; and,

e) deforming the pierced panel edge against the outer surface of the wall into the U-shaped channel, and driving the pierced panel edge into the U-shaped channel to deform the free end of the pierced edge and form a reinforcing enlarged annular bead on the pierced edge enclosed within and contacting the inner surface of the U-shaped channel, thereby forming a reinforcing mechanical interlock between the panel and the self-piercing and riveting annular wall of the fastener.

16. A method according to Claim 15, in which the

slug pierced from the panel has a diameter greater than the diameter of the inner surface of the annular wall and is forced into the space bounded by the wall in binding engagement with its inner surface, the slug supporting the inner surface and preventing collapse of the annular wall during deformaton of the free end portion.

17. A method according to Claim 15 or Claim 16, in which the die member includes a projecting central die portion which is coaxially aligned with and receivable within the inner surface of the annular wall and which has its free end including a central conical surface having a relatively sharp apex, the panel is deformed and domed on the central conical surface at the free end of the central die portion before the panel is pierced, and the pierced panel slug is centred and retained within the annular wall in engagement with its inner surface by the relatively sharp central conical surface after being carried into the space bounded by the wall.

18. A method according to any one of Claims 15 to 17, in which the body portion of the fastener body includes a radial flange extending outwardly generally perpendicular to the annular wall, and the pierced panel edge is driven into the U-shaped channel by the flange which thereby becomes recessed in the panel.

19. A method acording to any one of Claims 15 to 18, in which the fastener is a nut wherein the body portion includes a bore which is coaxially aligned with the annular wall, and the pierced panel slug is driven out of the open and of the annular wall by driving a punch through the bore after completion of the attachment of the nut to the panel.

20. A method according to any one of Claims 15 to 18, in which the fastener is a stud and the body portion comprises an elongated shank portion having a longitudinal axis generally coaxially aligned with the annular wall, and a radial flange located between the shank portion and the annular wall, and the slug is pierced from the panel with the piercing surface by driving on the radial flange.

21. A method of attaching a nut fastener to a panel, the nut fastener comprising a body portion having a nut bore and a self-piercing and riveting annular wall which projects from the body portion generally coaxially aligned with the nut bore and which has an open free end, the method comprising:—

a) locating the nut fastener opposite the panel with the free end of the annular wall facing the panel and a die member located on the opposite side of the panel, the die member having an annular die cavity and a projecting central die portion coaxially aligned with and receivable within the open end of the annular wall;

b) piercing a slug from the panel with the free end of the annular wall and receiving and supporting the panel slug on the projecting central die portion;

c) displacing the panel slug into the space bounded by the annular wall and retaining the slug on the projecting central die portion within the wall;

d) deforming the free end portion of the annular wall radially outwa:dly in the annular die cavity and deforming the pierced edge of the panel into a mechanical interlock with the deformed free end portion of the wall; and,

e) punching the panel slug out of the open end of the annular wall.

22. A method according to Claim 21, in which the free end portion of the annular wall is deformed into a generally U-shaped channel opening towards the body portion and the pierced edge of the panel, and the pierced panel edge is deformed against the outer surface of the annular wall into the U-shaped channel in forming the mechanical interlock between the annular wall and the panel.

23. A method according to Claim 22, in which the pierced panel edge is driven into the U-shaped channel, deforming the free end of the pierced panel edge in the U-shaped channel and forming a reinforcing enlarged annular bead on the pierced panel edge.

24. A method according to any one of Claims 21 to 23, in which the nut fastener is driven towards the panel by a second die member which includes a driving member engaging the body portion of the nut fastener and which has a bore aligned with the nut bore and a punch which is axially movable through the bores of the second die member and the nut, the panel slug being driven out of the annular wall by means of the punch after completion of the attachment of the nut fastener to the panel.

25. A method of attaching a self-fastening member to a panel, the self-fastening member comprising a base portion having a side surface and a bottom surface, and an annular wall which is integrally joined to the bottom surface of the base portion spaced inwardly from the side surface and which has an open free end portion, the method comprising:—

a) locating the self-fastening member opposite the panel with the free end portion of the annular wall facing the panel and a die member located on the opposite side of the panel, the die member having an annular die cavity surrounding a central projecting die portion amd a relatively flat panel supporting shoulder on opposite sides of the die cavity, the free end of the central die portion being spaced below the plane of the panel supporting shoulder and being coaxially aligned with and receivable in the open end of the annular wall, the central die portion having a relatively smooth arcuate concave outer surface extending through the bottom of the die cavity, and the outer surface of the annular die cavity comprising an inwardly inclined die surface extending from adjacent the shoulder into the die cavity and terminating in an annular lip spaced above the bottom of the die cavity;

b) supporting the panel on the shoulder of the die member in fixed relation thereto; and,

c) moving the self-fastening member and the die member relatively towards each other to perform the following method steps in a continuous operation;

(i) engaging the panel with the free end of the annular wall and deforming the panel into the annular die cavity,

(ii) disposing the free end of the central die portion into the open end of the annular wall through an opening in the panel,

(iii) deforming the free end portion of the annular wall radially outwardly against the arcuate concave outer surface of the central die portion, and deforming the panel adjacent the opening into the die cavity against the outer surface of the annular wall, and

(iv) further deforming the free end portion of the annular wall radially outwardly through the bottom surface of the die cavity to form a U-shaped channel opening towards the base portion of the self-fastening member and simultaneously driving the base portion into the panel and counter rotating the panel portion adjacent the opening in the developing U-shaped channel to form a mechanical interlock between the annular wall and the panel.

26. A method according to Claim 25, in which the free end portion of the annular wall comprises a piercing surface and the method includes piercing a slug from the panel, thereby forming the panel opening, and displacing the pierced panel slug into the annular wall on the central portion of the die member as the members move together, locating the panel slug within the annular wall at generally the point of greatest stress as the wall is deformed radially outwardly.

27. A method according to Claim 26, in which the piercing surface comprises an annular chamfer face inclined outwardly from the inner surface of the annular wall to its free end so that the slug pierced from the panel has a diameter greater than the internal diameter of the annular wall, and the slug is forced into the annular wall in binding engagement with its inner surface.

28. A die set assembly for attaching a fastener to a panel, comprising the fastener, which has a body portion and an annular self-piercing and riveting annular wall extending from the body portion and having inner and outer surfaces and an open free end portion having a piercing surface adjacent the inner surface, a first die member comprising an annular die cavity surrounding a projecting central die portion and a panel supporting shoulder on at least two sides of the die cavity, the free end of the projecting central die portion having a central conical surface facing the open free end of the fastener wall and a piercing surface which surrounds the conical surface at the outer edge of the free end of the projecting die portion and which is arranged to co-operate with the piercing surface of the fastener wall, the free end of the projecting central die portion being coaxially aligned with and receivable within the annular wall of the fastener, and the annular die cavity having an inclined die surface adjacent the piercing edge of the central die portion for receiving the free end portion of the fastener wall spaced from the bottom of the cavity, and a second die member for moving the fastener relative to the first die member to pierce a slug from a panel which, in use, is supported on the die shoulder between the co-operating piercing surfaces, the panel slug being received, supported and aligned on the conical surface of the central die portion within the annular wall, and the annular die cavity deforming the free end of the annular wall radially outwardly to form a mechanical interlock with the pierced edge of the panel.

29. A die set assembly according to Claim 28, in which the projecting central die portion is integral with the first die member and its conical surface is spaced below the plane of the panel supporting shoulder so that a panel will be first deformed from the plane of the shoulder into engagement with the conical die surface and thereby domed prior to having a slug pierced from it.

30. A die set assembly according to Claim 29, in which the surface of the free end portion of the annular wall adjacent the surface of the wall is arcuate so that a panel will be deformed into the die cavity, without piercing, until the piercing surfaces co-operate.

31. A die set assembly according to any one of Claims 28 to 30, in which the piercing surface of the fastener is formed by an annular chamfer at the open end of the annular wall lying at an outwardly inclined angle to the longitudinal axis of the annular wall such that a slug will be pierced from the panel having a diameter greater than the diameter of the inner surface of the annular wall.

32. A die set assembly according to any one of Claims 28 to 31, in which the annular wall of the fastener is closed by a bottom wall at the other end from its open free end and the conial surface on the central portion of the first die member is adapted to deform the pierced panel slug against the bottom wall to securely retain the slug within the annular wall.

33. A die set assembly according to Claim 32, in which the bottom wall is conical and convex to deform the panel slug radially outwardly into firm binding engagement with the inner surface of the annular wall.

34. A die set assembly according to any one of Claims 28 to 33, in which the free end of the projecting central portion of the die member has a flat annular surface surrounding the conical surface, and its piercing surface is a sharp edge defined by the outer edge of the flat annular surface and the inclined inner surface of the annular die cavity which are generally at right angles to each other.

35. A die set assembly according to Claim 28, in which the second die member includes a shoulder for engaging the fastener body and movable relative to the first die member to drive the fastener into engagement with the panel.

36. A die set assembly according to Claim 35, in which the fastener comprises a nut having a bore through its body portion generally coaxially aligned with the annular wall, and the second die member has a bore coaxially aligned with the nut bore and includes a punch which is movable axially through the bores of the second die member and the nut to punch the panel slug out of the anular wall after completion of the attachment of the fastener to the panel.

37. A die set assembly according to any one of Claims 28 to 36, in which the annular die cavity of the first die member comprises a relatively smooth concave arcuate annular surface extending from adjacent the piercing edge on the central die portion through the bottom of the die cavity to an annular lip spaced above the bottom surface for engaging and radially outwardly deforming the annular wall of the fastener, and an outer inclined surface extending between the panel supporting shoulder and the lip and merging smoothly therewith through arcuate surfaces for receiving the portion of the panel adjacent the pierced panel edge and guiding the panel into a mechanical interlock with the annular wall of the fastener.

38. A die member for securing a self-piercing fastener to a panel, the fastener having a body portion

and a piercing and riveting annular wall projecting from the body portion and including a piercing surface adjacent the free end of the inner surface of the wall, the die member comprising a body portion having an annular concave die cavity and a panel supporting shoulder located on at least two sides of the die cavity, and a central die portion projecting from and surrounded by the die cavity, the free end of the central die portion having a central conical surface with a relatively sharp apex and a relatively sharp piercing edge surrounding the conical surface at the outer edge of the free end, the piercing edge being adapted to generally co-operate with the piercing surface of the fastener to pierce a slug from a panel supported on the die shoulder, and the shoulder blending into an inclined surface of the die cavity for receiving the panel as the panel is deformed into the die cavity during installation of the fastener.

39. A die member according to Claim 28, in which the free end of the central die portion includes a substantially flat annular surface surrounding the conical surface, and the piercing edge is defined by the outer edge of the flat annular surface and the generally perpendicular inner surface of the annular die cavity.

40. A die member according to Claim 38 or Claim 39, in which the central die portion is integral with the body portion of the die member, and the conical surface on the free end of the central die portion is spaced below the shoulder so that a panel will first be deformed from the plane of the shoulder into engagement with the conical surface prior to having a slug pierced from it.

41. A die member according to Claim 40, in which the annular concave die cavity is semi-toroidal having a smooth arcuate surface on the central die portion for receiving the free end of the annular wall of the fastener and deforming the annular wall radially outwardly to form a mechanical interlock between the pierced edge of the panel and the deformed end of the annular wall.

42. A die member according to Claim 28, in which the annular concave die cavity comprises a smooth concave arcuate annular surface extending from adjacent the piercing edge of the central die portion through the bottom of the die cavity to an annular lip generally parallel to the shoulder and spaced above the bottom of the cavity, and the outer inclined surface of the die cavity extends between the shoulder and the lip, smoothly merging with the shoulder and lip through arcuate surfaces.

43. A die member for securing a self-piercing member to a panel, the self-piercing member having a body portion and a piercing and riveting integral skirt portion extending from the body portion, the die member comprising an annnular die cavity surrounding a central die portion projecting from the die cavity and a panel supporting shoulder on at least two sides of the die cavity, the free end of the projecting central die portion having a generally conical die surface and a surrounding piercing surface adapted to pierce a slug from a panel in co-operation with the skirt portion of the self-piercing member, and the free end of the central die portion being receivable in the open end of the skirt portion, the annular die cavity comprising a relatively smooth concave arcuate annular surface which extends from adjacent the piercing surface through the bottom of the die cavity to an annular lip spaced above the bottom of the die cavity and below the plane of the shoulder and which is arranged to receive the free end of the skirt portion and radially outwardly deform the skirt portion into an annular generally hook-shaped portion, and the die cavity including an inclined outer wall extending between and blending into the shoulder and the annular lip through relatively smooth arcuate surfaces for receiving the main portion of the panel adjacent the pierced panel edge, the annular lip supporting this portion of the panel as the pierced edge portion is deformed into the generally hook-shaped deformed skirt portion to form a mechanical interlock between the panel and the skirt portion.

44. A die member according to Claim 43, in which the conical die surface of the free end of the central die portion is centrally located on the free end and has a relatively sharp apex for receiving, centering and retaining the slug pierced from the panel by the piercing surface.

45. A die member according to Claim 44, in which the conical die surface of the central die portion is surrounded by an annular planar surface which is generally parallel to the panel supporting shoulder, and the piercing surface is a relatively sharp piercing edge surrounding the annular planar surface.

46. A die member according to any one of Claims 43 to 45, in which the central die portion is integral with the die member, and the conical surface is spaced below the plane of the panel supporting shoulder.

47. A self-piercing and riveting member for attachment to a panel, the member comprising a body portion, and a self-piercing and riveting annular wall which extends from the body portion and which has an outer surface, a generally smooth inner surface, and an open free end having an annular piercing face angled outwardly from the inner surface for piercing a slug from the panel having a diameter greater than the diameter of the inner surface, and a curved junction with the outer surface, the annular wall defining a socket for receiving the panel slug and having a bottom wall at the opposite end of the inner surface from the piercing face.

48. A self-piercing and riveting member according to Claim 47, in which the bottom wall of the socket is convex for permitting attachment of the member to a thin panel wherein the panel slug can be compressed against the convex bottom wall to deform the slug radially outwardly against the inner surface of the annular wall.

49. A self-piercing and riveting member according to Claim 47, in which the bottom wall of the socket is concave for permitting attachment of the member to a thick panel.

50. A self-piercing and riveting member according to any one of Claims 47 to 49, in which the junction between the body portion and the outer surface of the annular wall is arcuate.

51. A self-piercing and riveting member according to any one of Claims 47 to 50, in which the internal diameter of the inner surface of the annular wall adjacent the piercing face is at least equal to its

diameter adjacent the bottom wall.

52. A self-piercing and riveting member according to any one of Claims 47 to 51, in which the member is a stud, the body portion having a radial flange portion extending outwardly from the annular wall, and a stud shank portion extending from the flange portion on the opposite side from the annular wall and in generally coaxial alignment with the wall.

53. Apparatus for installing in a panel a self-piercing and riveting fastener having a body portion and a substantially coaxially aligned self-piercing and riveting annular wall extending from the body portion, the installation apparatus comprising a base member, a plunger which is movable with the base member, a nose member which is spaced from and movable relative to the base member and which has a plunger passage through which the plunger is slidable and a fastener feed passage communicating with the plunger passage, the plunger passage having a generally conical recess which receives and supports the self-piercing and riveting wall of a fastener fed into the plunger passage from the feed passage, thereby centering the fastener in the plunger passage ready for installation in a panel by the plunger, and the plunger having a bore in its leading end arranged to receive the free end of the fastener body portion upon movement of the nose member relative to the plunger following receipt of a fastener in the conical recess of the plunger passage to assure orientation of the fastener ready for installation, and actuating means for causing the apparatus to relatively move the plunger through the plunger passage to drive the oriented fastener out of the plunger passage and into a panel located opposite the passage.

54. Apparatus according to Claim 53, in which the fastener feed passage includes transfer means for feeding fasteners one at a time through the feed passage into the plunger passage with the fasteners generally oriented for the receipt of the self-piercing and riveting wall portion in the generally conical recess of the plunger passage.

55.Apparatus according to Claim 53 or Claim 54, in which the generally conical recess is defined by at least two spring biased members which are cammed apart by the fastener to allow the fastener out of the plunger passage when it is driven by the plunger against the conical surface defined by the spring biased members.

56. Apparatus according to any one of Claims 53 to 55, in which the base member is attached to a movable platen of a press, and the base and nose members are operably interconnected by a fluid pressure operated mechanism adapted to move the nose member relative to the base member to move the body portion of the fastener into the plunger bore, the actuating means operating the press to close the space between the members and drive the plunger through the plunger passage to install the fastener in the panel.

57. Apparatus according to any one of Claims 53 to 56, in which the fastener is a stud fastener, the body portion comprising a shank portion coaxially aligned with the self-piercing and riveting annular wall, and a radial flange portion between the shank portion and the annular wall, the plunger bore is arranged to receive the shank portion of the fastener, and the plunger has a generally flat end portion surrounding the bore for engaging the radial flange portion to drive the fastener through the conical recess and into the panel.

58. Apparatus for installing in a panel a self-piercing and riveting fatsener having an elongated body portion and a generally coaxially aligned self-piercing and riveting annular wall portion extending from the body portion, the apparatus comprising a housing having an elongated plunger reciprocable in a plunger passage, and the transfer means for feeding the fastener along a path transverse to and intersecting the plunger passage, the plunger having a longitudinally extending bore for receiving the elongated body portion of the fastener and an end portion arranged to bear against the annular wall portion, and the plunger being formed by at least two longitudinally extending parts which intersect the bore and of which a first part has a concave portion of the bore facing the transfer means feed path and a second part is movable relative to the first part and is adapted to close the bore and block the feed path, the apparatus also comprising actuation means for longitudinally moving the second plunger part relative to the first plunger part to open the concave bore portion of the first part and allow the transfer means to feed a fastener along the path into the plunger passage so that the body portion of the fastener is received in the bore portion of the first plunger part, thereby locating the fastener oriented for installation, and then closing the second plunger part around the body portion of the fastener before actuating means for driving the plunger through the plunger passage to install the oriented fastener in a panel located opposite the plunger passage.

59. Apparatus according to Claim 58, in which the fastener is a stud fastener and the body portion comprises an elongated shank portion coaxially aligned with the annular wall portion and a radial flange located between the shank and annular wall portions, the plunger bore is generally cylindrical and extends through the end portion of the plunger, and the bore portion of the first plunger part forms up to one-half of the cylindrical bore.

60. Apparatus according to Claim 58 or Claim 59, in which the actuation means includes pneumatic spring means for moving the second part of the plunger relative to the first part to open the plunger bore to receive a fastener.

61. Apparatus according to any one of Claims 58 to 60, in which the transfer means comprises a shuttle extending generally perpendicularly to the plunger passage and arranged to feed one fastener at a time to the plunger.

62. Apparatus according to Claim 61, which includes a chute communicating with a source of generally oriented fasteners and the shuttle, the chute including stop means allowing only one fastener at a time to be received by the shuttle.

63. Apparatus according to Claim 62 when dependent on Claim 59, in which the chute comprises a flexible cylindrical tube containing a plurality of the stud fasteners stacked so that each has its shank portion received within the annular wall of the following fastener.

64. Apparatus for installing a self-attaching stud fastener in a panel, the fastener comprising an elongated shank portion and a tubular riveting wall portion generally coaxially aligned with the shank portion and having an internal diameter greater than the diameter of the shank portion, the apparatus comprising an installation head having a plunger reciprocable in a plunger passage to install the fastener in a panel supported opposite the plunger passage, and transfer means for feeding fasteners from a source of the fasteners one at a time to the installation head, the transfer means including a flexible tube communicating with the source of fasteners and arranged to carry the fasteners in a flexible stack in which the elongated shank portion of each fastener is received in the tubular wall portion of the following fastener.

65. Apparatus according to Claim 64, in which the transfer means includes pneumatic means communicating with the flexible tube for injecting gas under pressure into the tube to move the stud fasteners through the tube.

66. A fastener secured to a panel, the fastener having a body portion and an annular wall portion which extends from the body portion and which comprises a first tubular portion adjacent the body portion and having generally parallel walls, and a second radially outwardly hook-shaped end portion, and the panel having a slug pierced from it by the annular wall and disposed in the first tubular portion of the wall in engagement with its internal surface, and a portion adjacent the pierced edge of the panel which is displaced from the plane of the main portion of the panel so that it engages the exterior surface of the first tubular portion of the annular wall and is deformed in the second hook-shaped portion, forming a mechanical interlock between the panel and the annular wall portion of the fastener.

67. An assembly according to Claim 66, in which the body portion of the fastener includes a portion bridging the annular wall and forming the bottom wall of a socket defined by the annular wall, the panel slug being deformed against the bottom wall in binding engagement with the internal surface of the first tubular portion of the annular wall.

68. An assembly according to Claim 67, in which the bottom wall of the socket is convex and the panel slug is spaced from the second hook-shaped portion of the annular wall.

69. An assembly according to any one of Claims 66 to 68, in which the hook-shaped portion of the annular wall opens towards the body portion of the fastener, and the pierced edge of the panel is deformed in the hook-shaped portion forming a reinforcing enlarged annular bead within the hook-shaped portion.

70. An assembly according to any one of Claims 66 to 69, in which the fastener body portion includes a radial flange adjacent the annular wall portion and extending radially beyond the first tubular portion of the wall, the flange being driven into and recessed below the plane of the main portion of the panel.

71. An assembly according to Claim 70, in which the surface of the radial flange remote from the annular wall portion is generally flush with the adjacent surface of the main portion of the panel.

72. An assembly according to Claim 66 in which the fastener is a stud fastener and its body portion comprises an elongated shank portion coaxially aligned with the first tubular portion of the annular wall portion, and a radial flange portion bridging the annular wall portion between the shank portion and the annular wall portion, the radial flange portion being recessed into the panel so that the shank portion extends from the plane of the main panel portion.

73. An assembly according to Claim 66, in which the fastener is a nut having a bore extending through the body portion coaxially aligned with the first tubular portion of the annular wall portion.

74. A panel having a fastener secured to it, the fastener comprising a body portion having a side face and an annular bottom face, and an annular barrel portion which has a first tubular portion integrally joined to the body portion radially inwardly of the annular bottom face and which terminates in a radially outwardly deformed U-shaped channel portion opening towards the body portion, and the panel comprising a main portion and a tubular L-shaped portion which is displaced from the plane of the main portion and which has a first portion in engagement with the side face of the fastener body portion and second inwardly projecting portion in engagement with the annular bottom face, the L-shaped portion of the panel terminating in a pierced edge which is deformed with the fastener barrel portion so that the portion of the panel adjacent the pierced edge substantiallly fills the U-shaped channel portion forming a secure mechanical interlock between the fastener and the panel.

75. An assembly according to Claim 74, in which the portion of the panel adjacent the pierced edge is deformed against the tubular barrel portion and forms an enlarged annular end portion within the U-shaped channel portion.

76. An assembly according to Claim 74 or Claim 75, in which the fastener is a stud fastener and the body portion comprises an elongated threaded shank portion coaxially aligned with the annular barrel portion and extending from a top face of the body portion remote from the annular barrel portion.

77. A method according to any one of Claims 1, 11, 15 and 25, substantially as described with reference to Figures 7 to 14 of the accompanying drawings.

78. A die member according to Claim 38 or Claim 43, substantially as described with reference to Figures 12 and 13 of the accompanying drawings.

79. A self-piercing and riveting member according to Claim 47, substantially as described with reference to Figure 7 of the accompanying drawings.

80. Apparatus according to Claim 53, substantially as described with reference to Figures 15 to 19 of the accompanying drawings.

81. Apparatus according to Claim 58 or Claim 64, substantially as described with reference to Figures 20 to 26 of the accompanying drawings.

82. An assembly according to Claim 66 or Claim 74, substantially as described with reference to Figure 14 or Figure 28 of the accompanying drawings.

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